TOPAS Summary

Date: Jan. 26, 2007

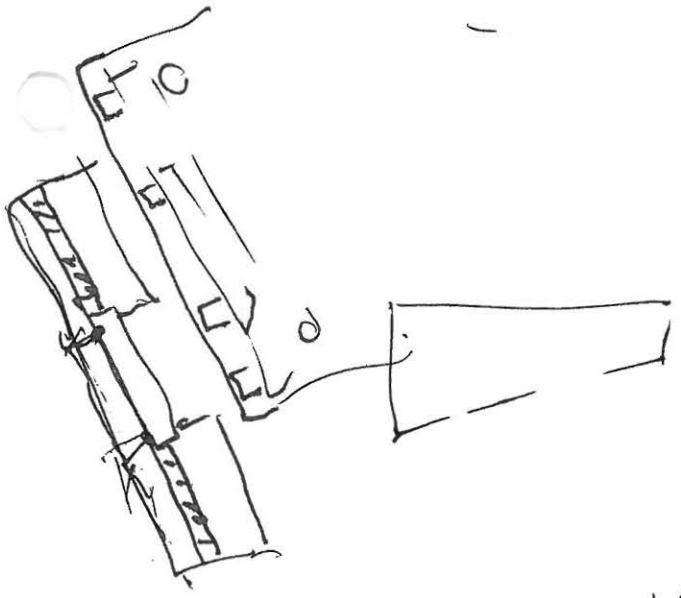
TOPAS-02236
(p = 800 nm)

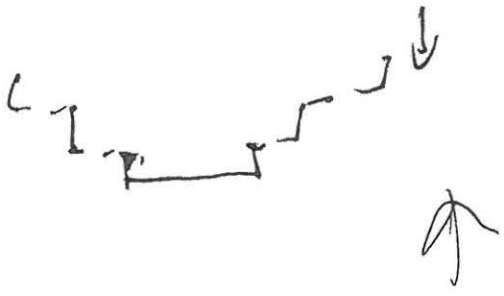
	wavelength range, nm		tuning curve (*.crv)	Mixer crystals (#)		Mixer rotation axis		Output polariz.	Output mirror (M12)
s	1140	1620	Main	-	-	-	-	V	In
i	1580	2680		-	-	-	-	H	In
dfg	2600	5000	DFG	8	-	H	-	H	In
	5000	30000		9	-	H	-	H	In

H-horizontal, V-vertical

Note 1: M12 must be in beam when DFG is used. Pump beam will damage the DFG crystal.
Note 2: DFG Delay Crystal (DFDC) is not used.

Empty position for mixer:
Mixer I - 2400





TOPAS OUTPUT ENERGY vs. WAVELENGTH

TOPAS 02236

Pump: Coherent Legend
$E_{pump} \approx 1.62$ mJ; Wavelength: 800nm (BW-10nm)

1. S+I (crystal #1B) Tuning Curve: main.crv Wavelength Range: 1140-2680 nm Output: TOPAS (M12 closed) Polarization: S-V, I-H	
S wavelength (nm)	S+I energy (μJ)
1140	75
1160	126
1180	201
1200	236
1220	226
1240	289
1260	290
1280	300
1300	320
1320	329
1340	333
1360	325
1380	309
1400	313
1420	315
1440	322

1. S+I (crystal #1) continued	
S wavelength (nm)	S+I energy (μJ)
1460	325
1480	320
1500	308
1520	310
1540	310
1560	303
1580	303
1600	296
1620	242

S-signal
I-idler
V-vertical
H-horizontal

10. DFG1 (crystal #8) Tuning Curve: DFG.crv Wavelength Range: 2600-5000 Output: Mixer 1 **(M12 closed)** DFDC out Polarization: H Crystal Rotating Axis: H	
wavelength (nm)	energy* (μJ)
2600	13.0
2800	11.9
3000	12.7
3400	12.4
3800	8.2
4200	5.5
4600	6.4
5000	5.0

10. DFG2 (crystal #9) Tuning Curve: DFG.crv Wavelength Range: 5000-30000 Output: Mixer 1 **(M12 closed)** DFDC out Polarization: H Crystal Rotating Axis: H	
wavelength (nm)	energy* (μJ)
5000	7.7
6000	7.4.
7000	9.0
8000	8.7
9000	7.8
10000	5.4
12000	5.0
14000	3.6
16000	2.8
18000	2.5
20000	2.3
22000	2.3
24000	2.3
26000	2.3
28000	2.3
30000	2.1

*background energy subtracted

DFG-difference frequency generation of signal and idler
DFG measured after ZnSe long pass filter
H-horizontal
V-vertical

LIGHT CONVERSION

TOPAS CONTROL SOFTWARE

"WinTOPAS" version 3.x

Start Guide

1. CPA Power
2. CPA pulsewidth
3. OPA 1st path alignment
4. OPA delay change

Ver. 1.00

March 28, 2006

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Notes

All information in this document applies to Microsoft Windows 2000, Microsoft Windows XP Professional and Microsoft Windows XP Home operating systems.

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Preface

"TOPAS" is a series of BBO or LBO crystal based optical ultrashort pulse parametric amplifier (OPA or NOPA) equipped with optional frequency converters providing generation of pulses continuously tunable over wide wavelength range. "TOPAS" operating system consists of I/O interface board that is installed in "TOPAS" module and Windows compatible software package "WinTOPAS". The main function of "WinTOPAS", is the control the hardware when the "TOPAS" wavelength tuning is performed. It also provides the user with number menu options for easy program installation, setting of "TOPAS" configuration, access to calibration and service procedures.

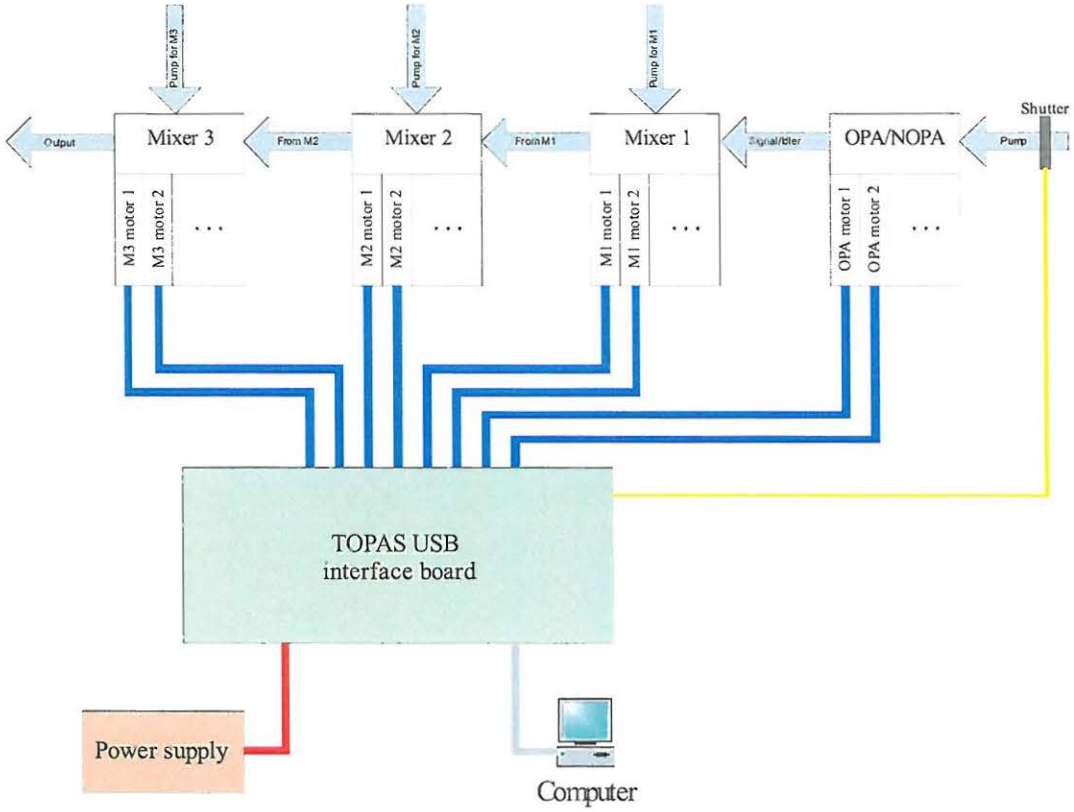


Figure 1. Structure of "TOPAS" system

Functional structure of the system is presented in Figure 1. The whole optical system can be represented as sequence of wavelength changers (OPA/NOPA, Mixer 1, Mixer 2 and Mixer3). Pump beam from laser is transformed to signal and idler waves in OPA/NOPA module. Mixer 1 uses OPA/NOPA signal or idler waves as input for further wavelength

transformations. Additional pump can be supplied to Mixer 1 for sum or difference frequency generations. In the same manner Mixer 2 uses output from Mixer1, and Mixer 3 output from Mixer 2. Every wavelength changing unit has dedicated motors. Up to six motors can be implemented in every unit. All motors are connected to "TOPAS" I/O board and over USB bus are controlled from "WinTOPAS" application. When asked for a new wavelength value, "WinTOPAS" finds all possibilities to set a new wavelength value, and, if possible, calculates positions of motors accordingly to formulas or tables of positions (saved in tuning files) and drives motors to new positions.

Single software package provides parallel operation of up to four I/O boards and every from them can drive up to 12 stepper motors installed in several units of frequency conversion and element positioning "WinTOPAS" has an intuitive graphical user interface that makes the control of "TOPAS" systems simple and straightforward. Being the fourth generation of software for computer controlled optical parametrical generators "WinTOPAS" is built and designed to meet the demands of researchers working in the fields of nonlinear optics, spectroscopy, biomedicine, etc.

This Start Guide provides the user with information on "WinTOPAS" main features and installation, and contains an overview of "TOPAS" system settings and control options accessible from control computer screen. In the last chapter a description of basic "WinTOPAS" operating procedures are presented.

1. System requirements

System requirements for operation of "WinTOPAS" are following:

- Computer with Pentium II or better processor,
- 64 Mbytes RAM (256 Mbytes recommended),
- 15 Mbytes on hard disk,
- SVGA color adapter (16-bits or more colors depth recommended),
- USB 1.1 or USB2 port,
- Windows 2000, Windows XP Professional, Windows XP Home Edition or Windows XP 64-bits edition.

2. General features

The list below describes the general features of "WinTOPAS".

- Fully computer controlled wavelength tuning in whole range from 180 nm to 20 μm.
- Four "TOPAS" devices can be operated simultaneously.
- Every device contains OPA/NOPA unit and up to three sequentially connected mixers.
- Support for "TOPAS" USB and legacy LPT interface cards.
- Up to 12 motors controlled with one interface card and up to 4 cards can be connected simultaneously.
- 32-bits application for Microsoft Windows compatible with Windows 2000 and Windows XP. (Older versions support Windows 98, Windows 95, MS-DOS).
- "WinTOPAS Software Development Kit" provides simple dll based interface to control "TOPAS" devices from external applications.
- Integrated serial port and TCP/IP network servers allow accepting control commands from remote computers via serial cable or local area network.
- Examples how to control "TOPAS" over TopasAPI functions from LabView, MatLab, Visual Basic and Visual C++.
- Context sensitive HTML help system.

3. Device installation

1. Connect external power supply to the "TOPAS" interface board.
2. Connect external power supply to the mains.
3. Install "WinTOPAS" software. "WinTOPAS" is provided as installation CD disk. Installation from CD should start automatically. If no, run Setup.exe file. Installation process will copy all necessary files (executables, dynamic link libraries, help system and "WinTOPAS SDK") to the default (C:\Program Files\WinTOPAS3) or user defined folder and will create shortcuts.
4. Copy device configuration file "*serial_number*.ini" from CD "Configuration files" folder to any folder on local computer ("WinTOPAS" default directory is recommended).
5. Connect USB or LPT cable to the "TOPAS" interface board and computer.

If "TOPAS" is equipped with LPT interface board, driver will be installed automatically when "WinTOPAS" will start for the first time.

If "TOPAS" is equipped with USB interface board, after plugging USB cable to computer system will detect a new device and will ask for a driver.

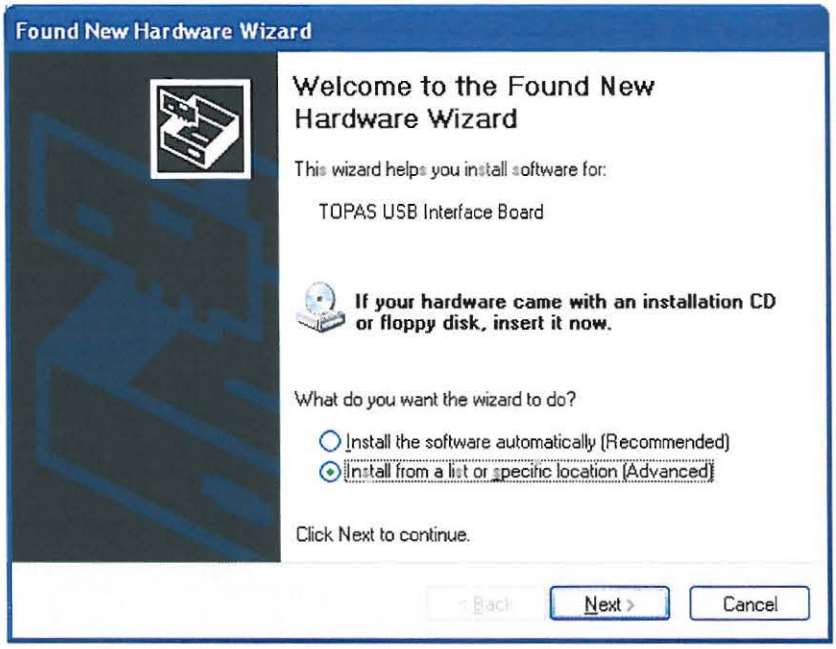


Figure 2. USB driver installation, step 1

Select "Install from a list or specific location (Advanced)" and press "Next" button. Windows will ask for path to driver.

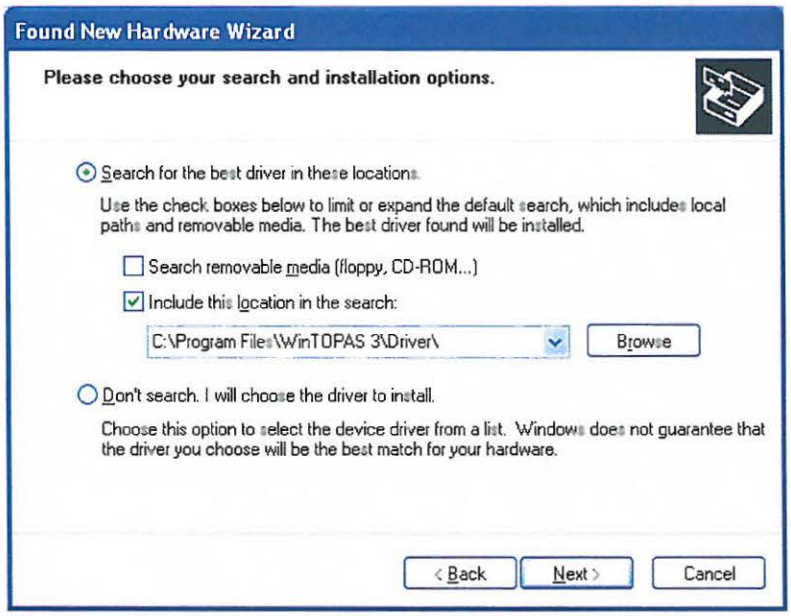


Figure 3. USB driver installation, step 2

Press "Browse" button and select "...\WinTOPAS 3 \Driver" directory. Press "Next" button. System will copy all necessary files.

Figure 4. USB driver installation, step 3

Press "Finish" button to complete installation. Start "WinTOPAS" application to check if installation was successful.

4. Device configuration

Typically device configuration is performed by authorized service engineer. User has to complete this operation only if software is moved to another computer.

- Select device configuration file/s.
  - Select "Service"->"Access level" menu option and switch access level to "advanced user" or "service engineer" (check printed "TOPAS" manual version for "advanced user" password).
  - Select "Load/Unload Devices Configurations" option in "Devices" menu.

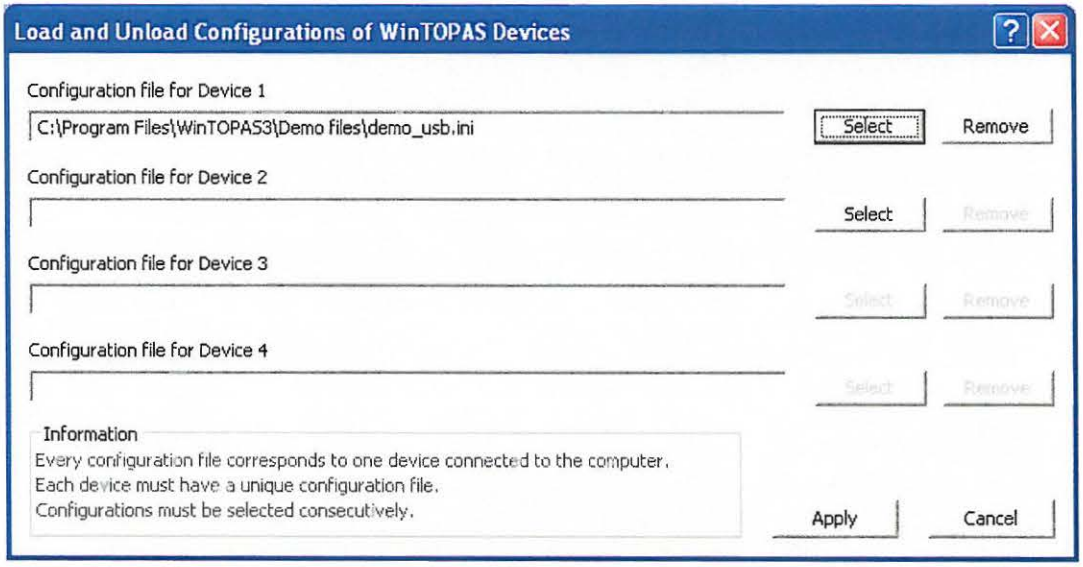


Figure 5. Selecting device configuration file

  - Press button "Select" and browse to device configuration file (typically configuration file resides in "/Configuration files" directory on WinTOPAS 3 installation CD and must be manually copied to any location on computer's hard disc. Configuration file contains all physical "TOPAS" system configuration parameters, information about used tuning curves and current "TOPAS" state, user's preferences and customization settings. Repeat the last step again if more than one "TOPAS" system is connected.

- Press "Apply" button to load configurations files and to connect to "TOPAS" devices.

- Select tuning curves files.
  - Select "Load/Unload Curves" option in "Curves" menu.
  - Press button "Load" of corresponding tuning curve (OPA/NOPA, Mixer I, Mixer II or Mixer III) and browse to tuning curve file. At the bottom of "Open" window short summary of currently selected tuning curve is displayed. Select the tuning curve and press button "Open" to load it. Repeat this procedure for all tuning curves.

After this reset operation of motors positions must be performed before "WinTOPAS" will be ready to use

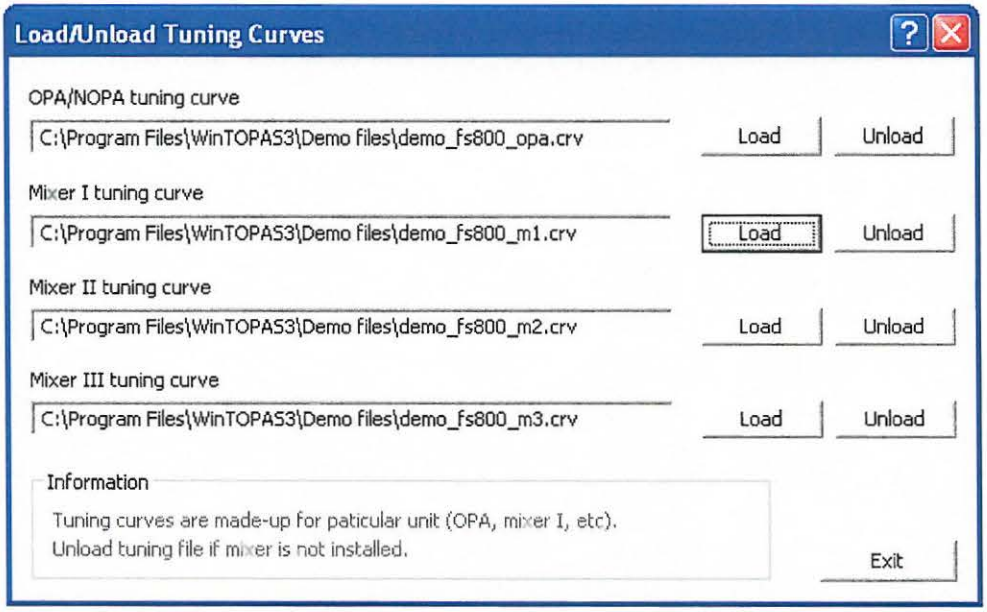


Figure 6. Loading tuning curves

5. Main application window

By default program is installed to "C:\Program Files\WinTOPAS3" directory. WinTOPAS3.exe file runs "TOPAS" control program. Just one "WinTOPAS" application can be started on the computer. It can control up to 4 "TOPAS" series devices but only one device (called "active") can be accessed at once. If several "TOPAS" devices have to be controlled from the same computer use different configuration files for every "TOPAS" device.

When the program is started, ***Main application window*** with Menu bar at the top, Info area in the center and the Status line with Toolbar with function keys are displayed.

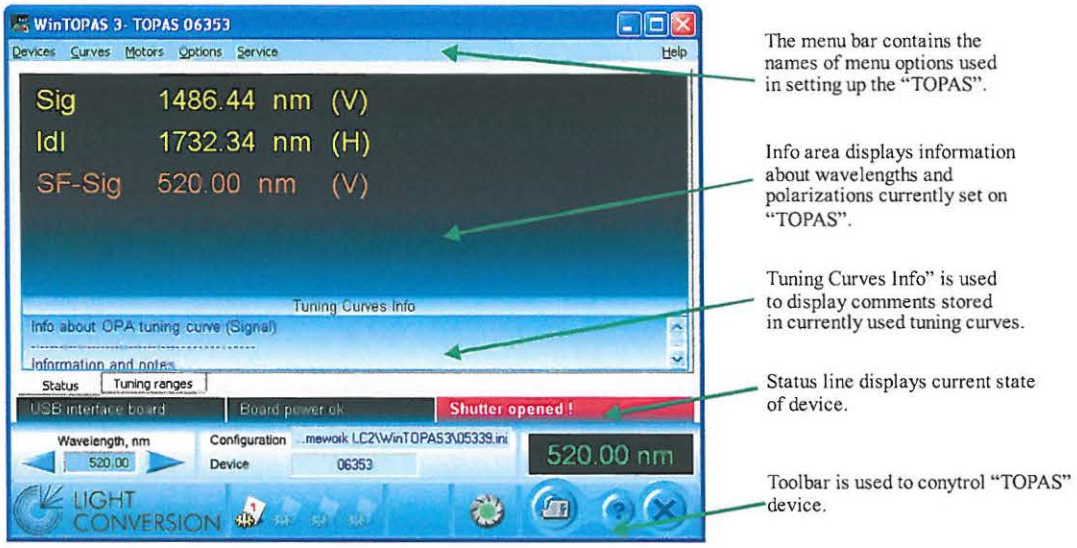


Figure 7. Main "WinTOPAS" application window

5.1. Info window

The "Info" window contains tab control with several pages.

"Status" page shows you the current status of "TOPAS" operation - wavelengths and polarizations of radiation generated by "TOPAS". First line of "Info" window displays the wavelength of the signal wave of OPA/NOPA. Second line contains information about wavelength of idler wave at the output of OPA/NOPA. If frequency mixers are used for the pulse generation at the required wavelength, the additional line(s) appear in the "*Status*" page. They contain the information about interaction types used in mixers, wavelengths and polarizations of the output pulses. The list of abbreviation for different types of interaction is presented in Appendix 1.

Wavelength can be displayed in nm or reciprocal centimeters accordingly to selected display mode. If position of any motor was changed from program using "Direct access" window the message "WAVELENGTH IS NOT SET" will appear at the top of Info window. "Tuning Curve Info" area at the bottom of the page displays description of all interactions used to produce output wavelength. These free-form descriptions are stored in

tuning curves files and can be edited in "Tuning Curves Properties" window. Descriptions for OPA/NOPA and mixers are separated with dashed lines.

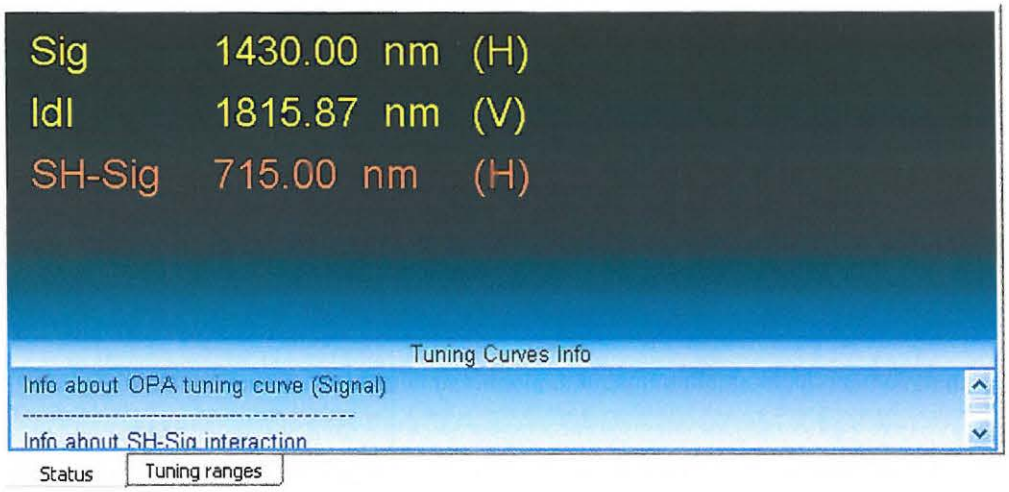


Figure 8. "Status" window

"Tuning ranges" page contains graphical representation of "TOPAS" tuning ranges provided by installed tuning curves. Every installed interaction type is displayed as colored box on the wavelength axe. Vertical or horizontal lines inside every box stand for the polarization of output wave. White horizontal dashed lines separate OPA/NOPA and mixers tuning curves.

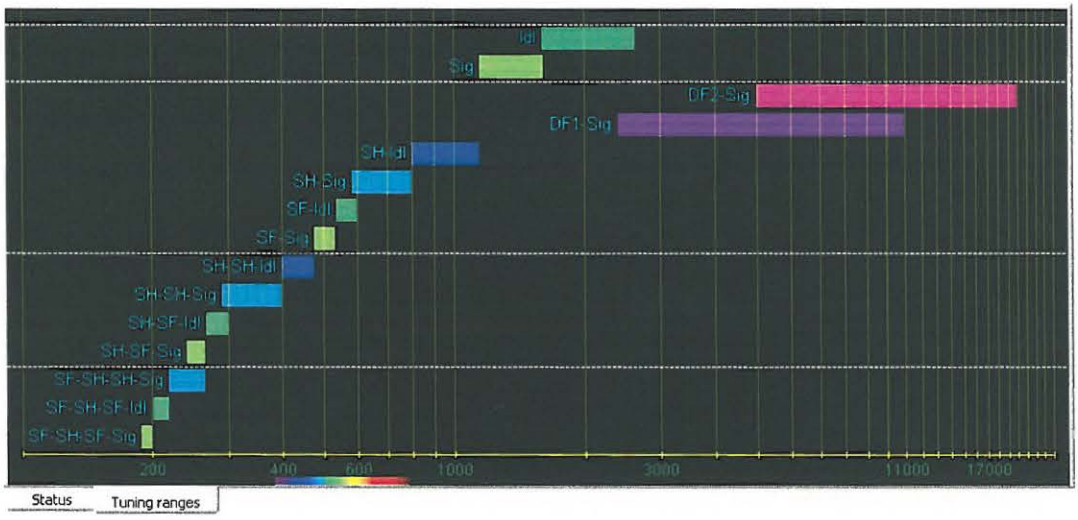


Figure 9. "Tuning ranges" window

5.2. Status line

The Status line displays current status of active device.

Figure 10. "TOPAS" status line

The first section of Status line displays type of interface board.

Table 1

Message	Explanation
USB interface board	Currently selected device is equipped with USB interface board.
LPT interface board	Currently selected device is equipped with LPT interface board.

If USB board is connected, the second section displays warnings about interface board power failure and short connections in stepper motor circuits.

Table 2

Message	Explanation
5V voltage failure !	USB interface board detected that 5V power supply voltage is out of range.
24V voltage failure !	USB interface board detected that 24V power supply voltage is out of range.
5V and 24V voltages failure !	USB interface board detected that 5V and 24V power supply voltages are out of range.

If USB board is connected, the third section displays current state of shutter and board flash memory status.

Table 3

Message	Explanation
Shutter opened !	"TOPAS" device input shutter is opened.
Shutter closed !	"TOPAS" device input shutter is closed and no radiation is inside the "TOPAS".
...Flash empty	Flash memory on USB interface card contains no data about

	last device state. Typically this message can be displayed after first powering of the interface board and disappears after restarting "WinTOPAS" program ("WinTOPAS" saves device state to flash on exit.)
...Not synchronized with PC	Device data stored in USB interface board differs from data stored in computers memory. This message can be shortly displayed after connecting to "TOPAS" devices and before data is transferred to interface board.

5.3. Menu bar

The menu bar contains the names of menu items for setting up the "TOPAS", measuring or correcting tuning curves, sending commands. The access to menu option selections depends on currently selected access level (see Appendix 2 for more information about "WinTOPAS" access levels). Some menu options won't be displayed if appropriate access level is not selected. "Service engineer level" must be switched on to gain full access to all menu options.

- **Devices**
  - **Load/Unload Devices Configurations**
    Opens the window to load and unload configuration files to connect or disconnect "TOPAS" devices. Up to 4 different "TOPAS" series devices can be connected simultaneously.
  - **Save Configuration**
    Saves current parameters of "active" "TOPAS" device to configuration file.
  - **Save Configuration As**
    Saves current parameters of "active" "TOPAS" device to a new configuration file prompting user for a new file name.
  - **Save All Configurations**
    Saves current parameters of all connected "TOPAS" devices.
  - **Exit WinTOPAS 3**
    Saves current parameters of all connected "TOPAS" devices and closes application.
- **Curves**

- **Load/Unload Curves**

  Opens the window to load and unload tuning curves for "active" "TOPAS" device. After tuning curves are loaded program tries to locate license for every interaction type. If license for particular interaction type is not located in device configuration file, the tuning curve corresponding to that interaction is removed from memory. See Appendix 3 for more details about licensing in "WinTOPAS".

- **Priorities**

  Calls the window that give a possibility to select between "Interactive" and "Priority" modes of program and modify the priority of interaction types. When setting the new wavelength the program browse the tuning files looking for the required wavelength recorded in files. When tuning ranges for different types of interaction overlap "TOPAS" can produce radiation with required wavelength in more than one way. In this case the program chooses the foremost opportunity in priority list, if "Priority mode" is selected, or allows user to make the choice through the dialog box, if "Interactive mode" is selected.

- **Curves Properties**

  Displays the window with properties of loaded tuning curves (interaction types, tuning ranges, offsets, pump wavelengths, polarizations).

- **Offsets**

  - **OPA/NOPA Offsets**

    Shows OPA/NOPA calibration dialog.

  - **Mixer I Offsets**

    Shows mixer I calibration dialog.

  - **Mixer II Offsets**

    Shows mixer II calibration dialog.

  - **Mixer III Offsets**

    Shows mixer III calibration dialog.

- **Create Tuning Curve**

  Calls series of windows that serve as a guide when measuring the tuning curves for OPA/NOPA and mixers.

- **Motors**

- **Direct Access**

  Calls the "Direct access" window. This window allows for direct control of all stepper motors used in "TOPAS" system.

- **Motors Properties**

  Displays the window with properties of installed motors. All parameters are read only in "user" and "advanced user" access levels.

- **Options**
  - **Windows**
    - **External commands window**

      Displays window to display commands received by "WinTOPAS" via COM port or via TCP/IP network.
  - **Preferences**

    Opens window with global options of "WinTOPAS" (wavelength or wave number display mode, wavelength step, shutter, backlash compensation and external commands servers options).
  - **Customize**

    Calls "Customize" window to change info window colors and font.
- **Service**
  - **Access Level**

    Opens "Access Level" selection dialog to switch to different access level (see Appendix 2 for more information about "WinTOPAS" access levels).
  - **Install licenses**

    Opens "Install licenses" window. See Appendix 3 for more details about licensing in "WinTOPAS".
  - **Testing workbench**

    Utility program used to test "TOPAS" mechanical modules.
  - **USB Board Diagnostics**

    Active only when USB interface board is connected. Displays diagnostics window used to troubleshoot hardware problems.
  - **Expo module**

    Module used to program sequences of wavelength changing operations.
- **Help**
  - **Contents**

    Shows contents of "WinTOPAS" help file.

- **About WinTOPAS 3**

  Presents the information on current "WinTOPAS" program version and contacts with program producers.

5.4. Toolbar

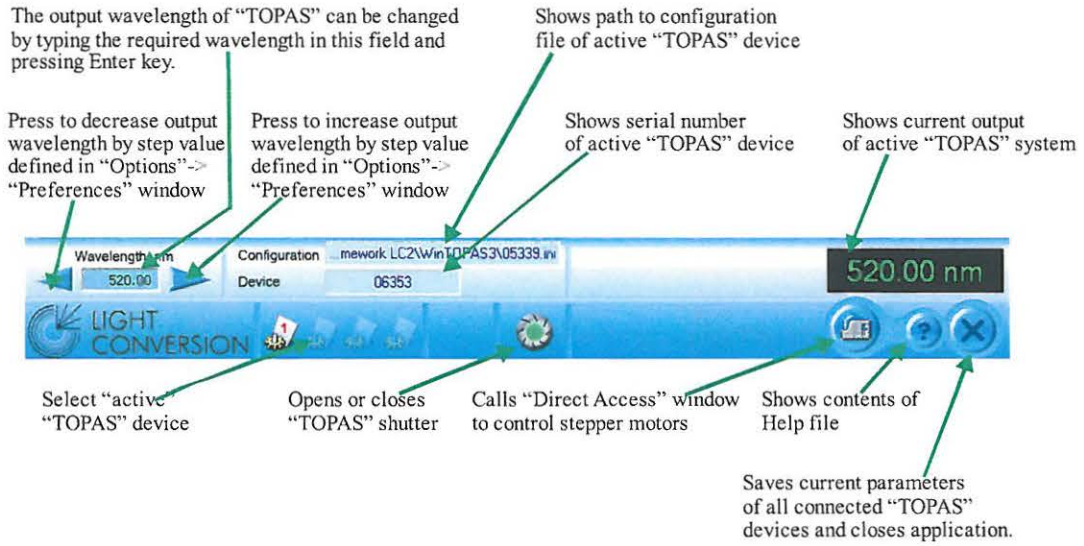


Figure 11. "WinTOPAS" main window toolbar

6. Basic operations

The complete "TOPAS" system configuration is set up by service personnel during initial system installation. For daily operation just few procedures usually are required to be performed by user when setting up the required wavelength(s) of "TOPAS" system output.

6.1. Starting the program

- Connect the 24V DC power supply cable to "DC/24V" socket located on the front panel of I/O interface board (s).

  ⚠ **On the *regular usage of system* it is recommended to keep "TOPAS" system powered permanently thus avoiding the need of motors position recalibration.**

- Run "WinTopas3.exe" file or the corresponding icon on the desktop of control computer. The **Main application window** with **Menu** bar at the top, **Info window** in the center, **Status line** and **Toolbar** will be displayed (see Chapter 5 "Main application window"). The system configuration and the settings are restored from current "TOPAS" configuration file, which is updated every time you exit the program.
- Select the "active" device by clicking the proper icon on the **Toolbar** of **Main application window.**

Important note: If power for interface board was switched off between software working sessions, you should run the stepper motor reset procedure. The procedure should performed also in case when computer controlled stages were adjusted manually during or in between of working sessions.

6.2. Reset of stepper motors

The values of "TOPAS" system output wavelengths as well as energy and radiation space-time quality characteristics rely on orientation and positions of optical elements which are installed on the rotation/translation stages of "TOPAS". These stages are driven by

computer controlled stepper motors, and their positions are loaded from the tuning file(s) when setting "TOPAS" operation at the defined wavelength. The motor reset procedure relates the true position of motor to the numerical motor position that is controlled by software.

- **Reset the stepper motors every time, if the knobs of the OPA/NOPA, mixers or other optional units were operated manually. Also perform reset after "TOPAS" control program fail due to any reason or power for "TOPAS" system devices were turned off.**

To reset stepper motors:

- Select "Direct access" option from "Motors" menu. The "Direct access" window will appear.

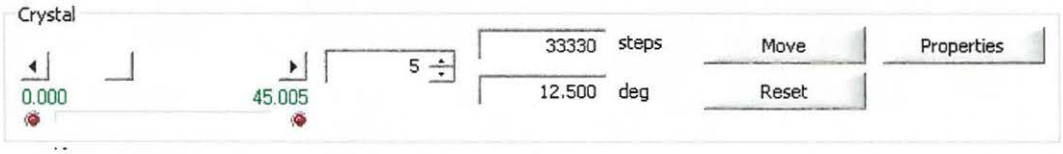


Figure 12. Reset of stepper motors

- Press "Reset" buttons of the motors which you are going to reset. The motor moves the stage to the minimum position. After activating of stage end-switch the program relates minimum mechanical stage position to "zero" numerical position. Finally the stage will be moved to initial numerical position.
- Repeat the reset procedure for the other motors if needed.

You can reset all the motors by clicking the button "Reset all" located at the left bottom corner of the window.

When reset procedure is finished set the desired device output wavelength from the **Main application window.**

6.3. Setting the output wavelength

The tuning range of each "TOPAS" system device is determined by the set of tuning curves included in the device configuration file. By clicking the "*Tuning ranges*" option of **Info window** you can activate the "Tuning ranges" page that contains graphical representation of "TOPAS" subunits tuning range provided by current configuration of the device. More

detailed information in numerical format on "TOPAS" tuning can be accessed through "Curves Properties" option of "Curves" menu.

When setting the required wavelength you can express it both in nanometers (nm) and wave numbers (cm^{-1}).

- Select the option "Preferences" from the "Options" menu. The new window "Preferences" will appear.
- Select a desirable format (in "nm" or in "cm^{-1}") for wavelength setting. In the same window you can set the number of significant digits with which the wavelength is expressed.

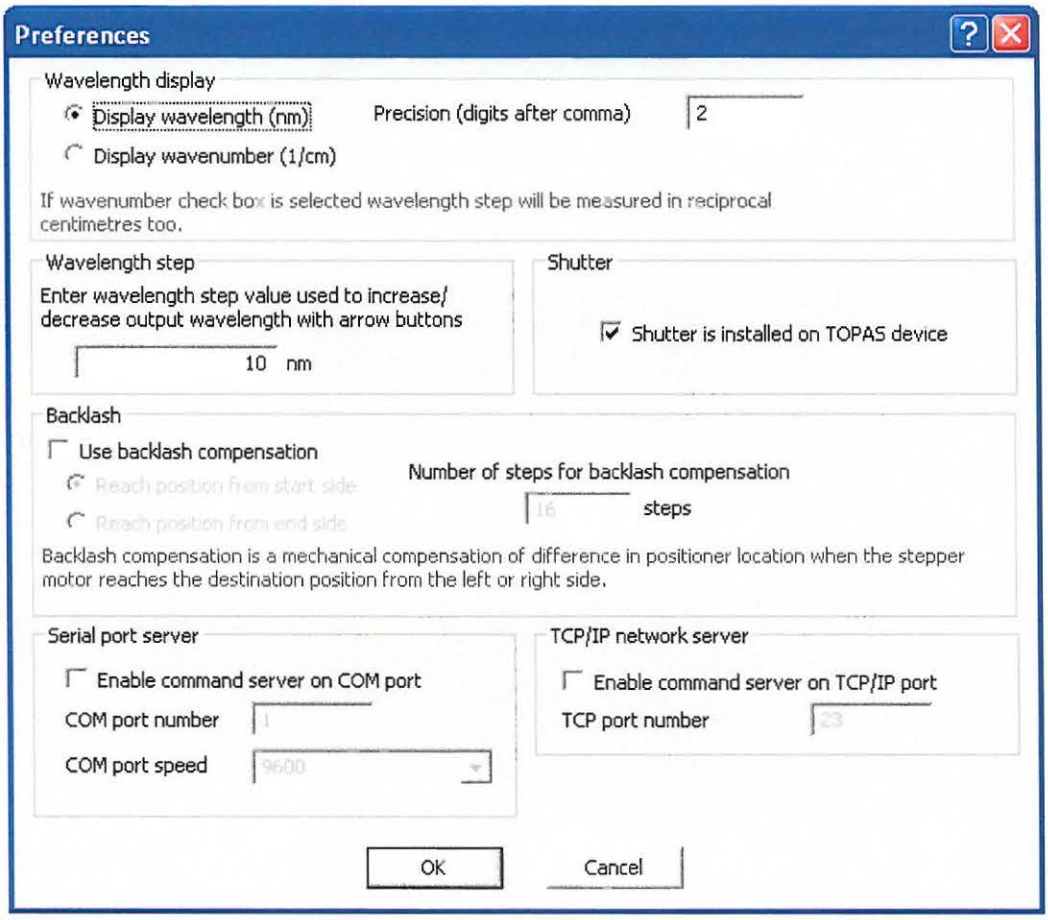


Figure 13. Preferences window

"TOPAS" output wavelength is set using the input field named "Wavelength, nm"(or "Wavenumber, cm^{-1}"), that is located on the left side of the **Toolbar** of **Main application window.**

- Type the required wavelength in the field and press "Enter". The new window with a progress bar will appear displaying the status of procedure execution. When the wavelength is set the information on wavelength and polarization of radiation produced by all device subunits involved in setting of required output wavelength will be displayed in the **Info window.**

The output wavelength can be changed by fixed value clicking  or  buttons located on the both sides of the wavelength input field. The value of the wavelength shift is set using option "Preferences" from the "Options" menu.

It could be the "conflict" situation when the certain wavelength of output radiation can be obtained using different interaction types, i.e. the tuning curves for different subunits overlap in certain range of wavelengths. For solving of theses cases "WinTOPAS" provides the user with two operation modes for setting of interaction type priorities.

- Select the "Priorities" option from "Curves" menu. You will be presented with window "Set priorities for interaction types"

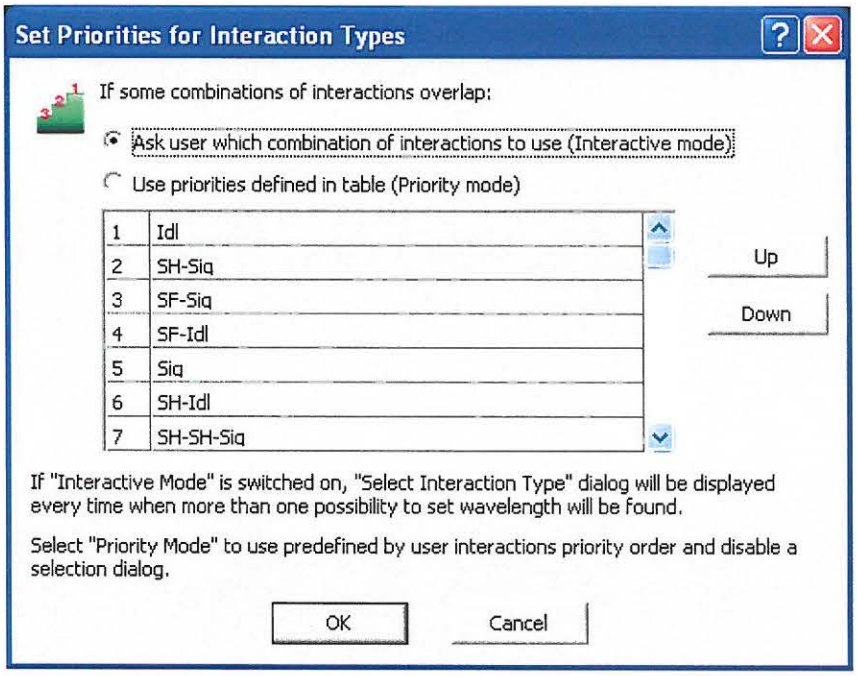


Figure 14. Priority mode selection dialog

- Select the "Interactive mode" or "Priority mode" by checking the corresponding field.

When working in the "Interactive mode" every time when more than one possibility to set the required wavelength occur the user will be asked to choose the preferable interaction type from the list that will be presented in the "set interaction type" dialog box.

When working in the "Priority mode" the program will choose automatically the needed interaction type from the user predefined priority list. This list is presented in the window "Set priorities for interaction types". You can modify the priority order by selecting the certain interaction type and clicking the buttons "Up" or "Down".

Appendix 1

Abbreviations used in "WinTOPAS"

Table 4

Sig	Signal wave
Idl	Idler wave
SH	Second harmonic
SF	Sum frequency with additional pump
DF, DF1, DF2	Difference frequency of signal and idler waves
DFP	Difference frequency of pump and idler waves

Every combination of interaction types in "TOPAS" devices is described as line of abbreviations. Interactions in different units (OPA/NOPA, mixer I, II, and III) are separated with symbol "-". For example:

SH-Sig (second harmonic of signal wave) (mixer I generates second harmonic of signal wave from OPA output),

SF-SH-Idl (sum frequency of second harmonic of idler wave) (mixer II generates sum frequency of additional pump and output from mixer I, mixer I generates second harmonic of idler wave from OPA output), etc.

Appendix 2

"WinTOPAS" access levels

To protect sensitive device related information there is three access levels introduced in "WinTOPAS":

- user level,
- advanced user level,
- service engineer level.

Access level can be changed from the main program menu ("Service"->"Access level"). Two higher access levels are password protected. Summary of right is presented in table bellow.

Table 5. Summary of user rights

Operation	User	Advanced user	Service engineer
Change wavelength	yes	yes	yes
Switch between TOPAS devices	yes	yes	yes
Move and reset motors	yes	yes	yes
Load/ unload device configuration files	no	yes	yes
Save configuration files	yes	yes	yes
Load/ unload tuning files for selected device	yes	yes	yes
Change priority order of interaction types	yes	yes	yes
Change parameters of tuning curves	no	yes	yes
Calibrate tuning curves	no	yes	yes
Measure new tuning curves	no	yes	yes
Install licenses for interaction types	yes	yes	yes
Change motors parameters	no	no	yes

Appendix 3

"WinTOPAS" licensing model

"WinTOPAS" ver.3.x introduces licensing for using different combinations of interactions. Every license is issued for particular "TOPAS" device (accordingly to it's serial number) and for particular combination of interactions used in OPA/NOPA and mixers. For example there will be different licenses for interactions combinations Sig, SH-Sig, SF-SH-Idl, etc. License is represented by string of 16 hexadecimal symbols and can be preinstalled with "WinTOPAS" software or bought and installed later by user. To install a new license:

- Open "Install Licenses" dialog (menu option "Service"->"Install Licenses"),
- Copy license string to edit box,
- Press "Install" button.

Check if a new license appeared in "Installed licenses" list.

Licenses are checked when tuning curves are loaded. Software try to locate license in device configuration file for every interaction type loaded from tuning curve file. Interaction is deleted from memory if there is no license found.

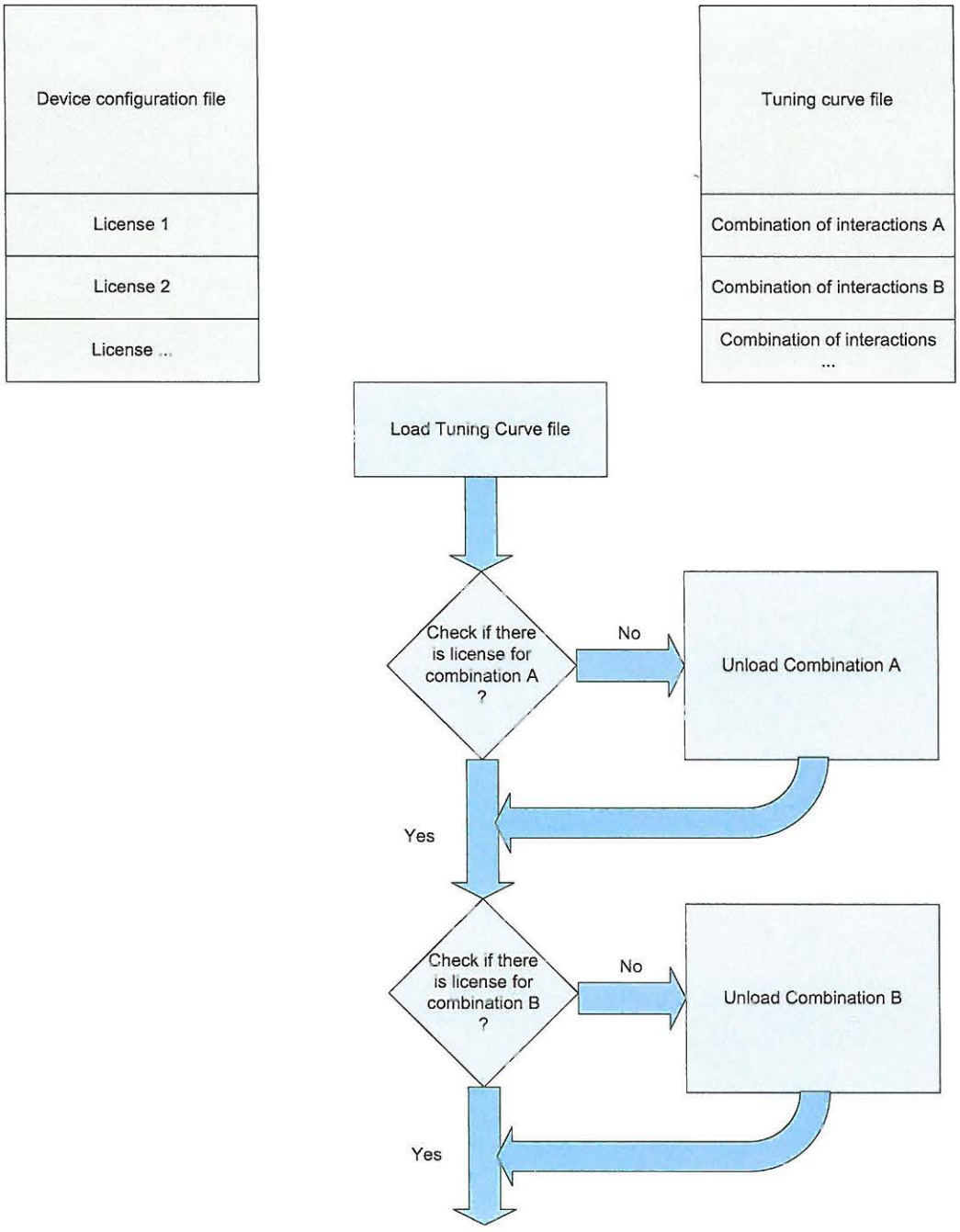


Figure 15. "WinTOPAS" license model

Date (data)_14/_03/_03
DD MM YY

ŠVIESOS KONVERSIJA

Service Report No. _DP-118

(Atliktų darbų aktas Nr.)

LIGHT CONVERSION Ltd., P.O. Box.1485 LT-2040 Vilnius, Lithuania
UŽDAROJI AKCINĖ BENDROVĖ MGF "Šviesos Konversija"
Tel:+370 5 2491830, Fax:+370 5 2698723

Customer (užsakovas)		**System** (objektas)
Name (organizacija): National High Magnetic Field Laboratory, Florida SU		Model: Topas
Address (adresas): 1800 E. Paul Dirac Dr. Tallahassee, FL 32310-3706		8044
		Ser. No: 02236
Contact person (kontakt. asmuo) Dr. Young-Dahl Cho		
Tel: 850-645-3265 Fax:	E-mail: ydjho@magnet.fsu.edu	
☑ **Installation** (instaliacija) ☐ **Warranty** (garantinis) ☐ **Nonwarranty** (pogarantinis)		
Service (Darbai)	Installed Topas-02236 – SH/SF + 4H + DF1/DF2	
Pump: Clark-MXR CPA-2001. E_{Topas}=740 μJ, τ~150 fs, λ=775.6 nm, f=1 kHz. Tilt of pump pulses: horizontal – 30 μm per 5 mm beam, vertical - ~80 μm/ 5 mm. Tilt of pulses is not removable due to construction of compressor of CPA-2001 (roof prism H and V retroreflectors).		
Topas energies at signal wavelength (s&i, μJ @ nm): 130 @ 1100, 197 @ 1200, 207 @ 1300, 203 @ 1400, 201 @ 1500, 220 @1550		
SHI energies: 57.9 @ 780, 50.7 @ 800, 33.3 @ 900, 20.8 @ 1000, 8.7 @ 1100		
SHS: 37 @ 550, 68.7 @ 600, 67 @ 650, 60 @ 700, 60 @ 750, 58 @ 775		
SF: 76.5 @ 455, 110 @ 465, 83 @ 490, 74 @ 515, 40.7 @ 520, 39 @ 530, 38 @ 550, 54 @ 570		
4HI: 20.5 @ 390, 15.5 @ 410, 13.2 @ 430, 10.4 @ 450, 7 @ 470		
4HS: 5.5 @ 275, 18.3 @ 290, 22.1 @ 310, 18.8 @ 330, 16.5 @ 350, 18.1 @ 370, 17.6 @ 387.5		
SHSF: 5.7 @ 227.5, 12.3 @ 235, 11.1 @ 245, 9.1 @ 255, 2.64 @ 265, 2.4 @ 275, 3.75 @ 285		
DF1 ($AgGaS_2$), μJ @ nm: 5.6 @ 4, 3.8 @ 5, 2.13 @ 7, 1.74 @ 9, 1.48 @ 10, 1.27 @ 11, 0.99 @ 12		
DF2 (GaSe): 5.05 @ 4.5, 2.42 @ 8, 1.79 @ 10, 1.52 @ 12, 1.3 @ 14, 1.06 @ 16, 0.85 @ 18, 0.61@ 20		
Measured tuning curves: 774.crv, shi774.crv, shs774.crv, sf774.crv, 4hi774.crv, 4hs774.crv, shsf774.crv, df1774.crv, df2774.crv		
P.S. Full list of output energies attached in appendix to service report.		
Labour (Darbų trukmė) 40 **hrs.** (val.)		
Payment of service according invoice (Apmokėjimas pagal sąskaitą)	☐ **Yes** (taip)	☒ **No** (ne)

Field engineer (vykdytojas) Physicist (fizikas) Donatas Podėnas Position, name, surname, signature (pareigos, vardas, pavardė, parašas)	**Customer** (užsakovas) Young-Dahl Cho Position, name, surname, signature (pareigos, vardas, pavardė, parašas)
Date (data) 14/03/03	**Date** (data) 03/14/03

Appendix to Service Report No _DP-118_(6 pages)

TOPAS OUTPUT ENERGIES vs OUTPUT WAVELENGTH

System: TOPAS -SH/SF + 4H + DF1/DF2

Serial No: 02236

PUMP PARAMETERS:

Pump source: _Clark-MXR CPA-2001

Pump energy: _0.774 mJ

Wavelength: _775.6 nm

Pulse width (FWHM): _~150 fs. Tilt: V - 80 um/5 mm, H- 30 um/5 mm

Bandwidth (FWHM): _5.5 nm

1. S+I, crystal #1 **Tuning curve: 774.crv** **Wavelength range: 1100-2620 nm** **Polarization: S- V, I- H** **Output from: TOPAS** **M12 closed**	
S wavelength, nm	S+I Energy, μJ
1100	130
1120	159
11440	181
1160	189
1180	190
1200	197
1220	203
1240	208
1260	211
1280	210
1300	207
1320	207
1340	204

1. S+I, crystal #1 (continued)	
S wavelength, nm	S+I Energy, μJ
1360	201
1380	203
1400	203
1420	208
1440	209
1460	208
1480	202
1500	201
1520	211
1540	212
1550	220

S- signal
I- idler V- vertical

2. SHI, crystal #2 Tuning curve: SHI774.crv Wavelength range: 776.3-1100 nm Output from: Mixer I Crystal rot. axis: H Polarization: V M12 closed	
wavelength, nm	Energy, μJ
776.3	59.5
780	57.9
790	53.5
800	50.7
820	47.7
840	46
860	41.2
880	37
900	33.3
920	29.6
940	26.7
960	25.5
980	23.5
1000	20.8
1020	18.3
1040	15.4
1060	12.9
1080	11.3
1100	8.7

3. SHS, crystal #2 Tuning curve: SHS774.crv Wavelength range: 550-775 nm Output from: Mixer I Crystal rot. axis: V Polarization: H M12 closed	
wavelength, nm	Energy, μJ
550	37
560	49
570	60
580	67.5
590	68.5
600	68.7
610	72.5
620	73
630	70
640	70
650	67
660	66
670	66
680	63
690	62
700	60
720	62
740	61
760	61
770	61
775	58

SHI measured after _WS(730-930), WS(920-1150)

SHS measured after _WS(450-650), WS(630-750), WS(730-930)

SHI- second harmonic of idler

SHS- second harmonic of signal

WS- wavelength separator

H-horizontal

V-vertical

4. SFI, crystal #2 Tuning curve: SF744.crv Wavelength range: 517.201-570 nm Output from: Mixer I Crystal rot. axis: H Polarization: V M12 opened	
wavelength, nm	Energy, μJ
520	40.7
525	35
530	39
535	38.7
540	39
545	37
550	38
555	39
560	42
570	54

5. SFS, crystal #3 Tuning curve: SF774.crv Wavelength range: 455-516.933 nm Output from: Mixer I Crystal rot. axis: H Polarization: V M12 opened	
wavelength, nm	Energy, μJ
455	76.5
460	95
465	110
470	105
475	102
480	94
490	83
500	78
510	69
516.93	73

SFI measured after WS(450-650)

SFS measured after WS(380-480), WS (450-650)

SFI- sum frequency of Pump and idler
SFS- sum frequency of pump and signal
WS- wavelength separator

H-horizontal
V-vertical

6. FHI, crystal #5 Tuning curve: 4HI744.crv Wavelength range: 388.2-470 nm Output from: Mixer II Crystal rot. axis: V Polarization: H M12 closed	
wavelength, nm	Energy, μJ
390	20.5
400	16
410	15.5
420	15
430	13.2
440	11.5
450	10.4
460	8.6
470	7

7. FHS, crystal #5 Tuning curve: 4HS744.crv Wavelength range: 275-387.5 nm Output from: Mixer II Crystal rot. axis: H Polarization: V M12 closed	
wavelength, nm	Energy, μJ
275	5.5
280	10.1
290	18.3
300	18.9
310	22.1
320	21.2
330	18.8
340	18.1
350	16.5
360	17.8
370	18.1
380	17.4
387.5	17.6

FHI measured after WS(380-480)

FHS measured after WS(230-300), WS(300-380), WS(380-480)

FHI- fourth harmonic of idler
FHS- fourth harmonic of signal
WS- wavelength separator

H-horizontal
V-vertical

8. SH(SFI), crystal #6
Tuning curve:SHSF774.crv
Wavelength range: 258.601-285 nm
Output from: Mixer II
Crystal rot. axis: V
Polarization: H
M12 opened

wavelength, nm	Energy, μJ	
258.601	3.1	
260	2.8	5 μJ
262.5	2.4	
265	2.64	
267.5	2.56	
270	2.58	5 μJ
272.5	2.33	
275	2.4	
277.5	2.47	
280	2.67	6 μJ
282.5	3.15	
285	3.75	

9. SH(SFS), crystal #6
Tuning curve:SHSF774.crv
Wavelength range: 227.5-258.446 nm
Output from: Mixer II
Crystal rot. axis: V
Polarization: H
M12 opened

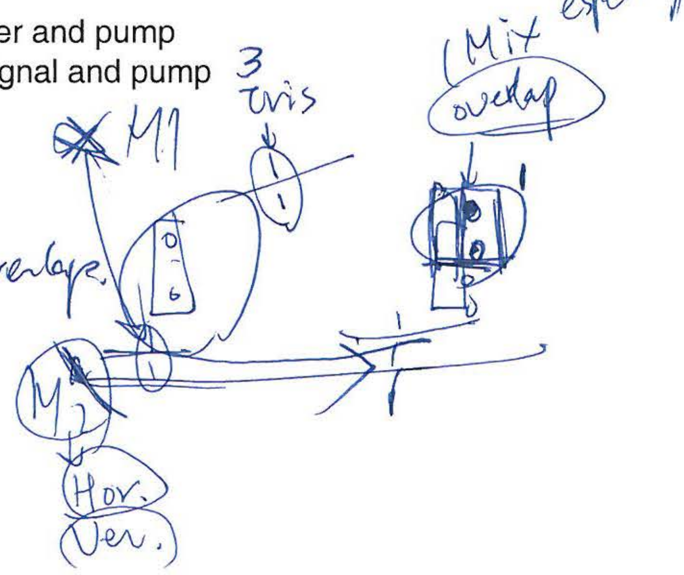
wavelength, nm	Energy, μJ	
227.5	5.7	
230	7.6	8 μJ
232.5	11.5	
235	12.3	
237.5	12.8	
240	12.4	9 μJ
242.5	11.8	
245	11.1	
247.5	10.2	
250	10.3	7.5 μJ
252.5	10.3	
255	9.1	
257.5	9.2	
258.466	9	

SH(SFI) measured after FS prism
SH(SFS) measured after FS prism

SH(SFI)- second harmonic of sum frequency of idler and pump
SH(SFS)- second harmonic of sum frequency of signal and pump
WS- wavelength separator

H-horizontal
V-vertical

1. (1-3μm → 3 color overlape.
774A ← new file
2. Iris
3. lens + Tricky =



10. DFG1, crystal #8 Tuning curve: DF1774.crv Wavelength range: 2600-13000 nm Output from: Mixer 1 Crystal rot. axis: H Polarization: H M12 closed	
wavelength, nm	Energy, μJ
2600	6.8
3000	8.1
3400	6.8
3800	6.4
4200	4.6
4600	4.8
5000	3.8
6000	2.56
7000	2.13
8000	2.22
9000	1.74
10000	1.48
11000	1.27
12000	0.99
13000	0.64

11. DFG2, crystal #9 Tuning curve: DF2774.crv Wavelength range: 4500-26000 nm Output from: Mixer 1 Crystal rot. axis: H Polarization: H M12 closed	
wavelength, nm	Energy, μJ
4500	5.05
5000	4.3
7500	2.38
9000	2.03
10000	1.79
12000	1.52
14000	1.3
16000	1.06
18000	0.85
20000	0.61
22000	0.43
24000	0.29
26000	0.2

DFG1 measured after ZnSe Mid-IR filter

DFG2 measured after ZnSe Mid-IR filter

DFG- difference frequency mixing of Topas signal and idler

H-horizontal

V-vertical

11/03/03 FSU

Pump CPA-2001, λ_p = 773.5 (774.1), E_{TOPAS} = 0.75 mJ

$\Delta\lambda$ = 5.5 nm ⇒ 92 cm⁻¹ (163 fs)

Topas-02236

λ_s = 1280 nm   s+i+shs = 183 μJ   s+i+p = 527

18.731 (6243)   5.651 (6510)   22.58 (9780)   2.833 (7370)

λ = 1100

16.766 (5538)   5.621 (6475)   19.27 (9702)   120.083 (7205)

12/03   773 crv (14/03)

λ_s	$E_{s+i+shs}$	E_{s+i}	λ_s	$E_{s+i+shs}$	E_{s+i}
1100	122	130	1400	181	203
1120	149	159	1420	186	208
1140	164	181	1440	189	209
1160	170	189	1460	190	208
1180	169	190	1480	188	202
1200	176	197	1500	188	201
1220	180	203	1520	187	211
1240	186	208	1540	184	212
1260	186	211	1560	185	220
1280	186	210			
1300	183	207			
1320	184	207			
1340	188	204			
1360	184	201			
1380	180	203			

Tilt of pump pulses. Vertical / ↕ 5mm (80 μm)   tilt ~ 80 μm / 5mm

Horizontal / _ 5mm (30 μm)   ~ 30 μm / 5mm

~ 3.3 fs

λ_p = 774.1 nm   SHG and SFG gives this λ.

Crystals #2, 3, 5, 6 : orientation OK.

13/03   Pump to Topas ~ 720 μJ @ 774.1 nm

9 - 2.5 = 6.5 μJ @ 4 μm ($AgGaS_2$)

Orientations ~~for~~ of # 829 OK

λ_{4HS}	$E_{4HS}+b$	b	E_{4HS}	λ_{4HS}	$E_{4HS}+b$	b	E_{4HS}
275	10.2	4.7	5.5	340	20.4	2.3	18.1
280	14.3	4.2	10.1	345	19.7	2.6	17.1
285	18.5	3.9	14.6	350	19.5	3.0	16.5
290	21.5	3.2	18.3	355	20.9	3.5	17.4
295	21.5	2.8	18.7	360	21.8	4.0	17.8
300	21.2	2.3	18.9	365	21.9	4.5	17.4
305	25.2	3.6	21.6	370	22.5	4.4	18.1
310	25.0	2.9	22.1	375	22.2	4.7	17.5
315	24.5	2.4	22.1	380	21.7	4.3	17.4
320	23.3	2.1	21.2	385	21.4	4.5	16.9
325	21.5	2.0	19.5	387.5	22.2	4.6	17.6
330	20.8	2.0	18.8				
335	21.0	2.3	18.7				

4HI774.crv

λ_{4HI}	$E_{4HI}+b$	b	E_{4HI}	λ_{4HI}	$E_{4HI}+b$	b	E_{4HI}
388.2	22.1	3.9	18.2	440	13.8	2.3	11.5
390	25.1	4.6	20.5	445	13.0	2.0	11.0
395	21.3	4.5	16.8	450	12.3	1.9	10.4
400	20.3	4.3	16.0	455	11.4	1.8	9.6
405	19.7	4.1	15.6	460	10.4	1.8	8.6
410	19.5	4.0	15.5	465	9.5	1.8	7.7
415	19.1	3.8	15.3	470	8.9	1.9	7.0
420	18.6	3.6	15.0				
425	17.3	3.2	14.1				
430	16.1	2.9	13.2				
435	14.9	2.6	12.3				

258.466
258.601

SHSF774.crv (λ separated (in prism))

λ_{SHSF}	E_{SHSF}	λ_{SHSF}	E_{SHSF}
227.5	5.7	258.601	3.1
230	7.6	260	2.8
232.5	11.5	262.5	2.4
235	12.3	265	2.64
237.5	12.8	267.5	2.56
240	12.4	270	2.58
242.5	11.8	272.5	2.33
245	11.1	275	2.40
247.5	10.2	277.5	2.47
250	10.3	280	2.67
252.5	10.3	282.5	3.15
255	9.1	285	3.15
257.5	9.2		
258.466	9.0		

Evening: 175 mJ @ SH+4 Mix1+Mix2 @ 270nm (pump blocked)

SH1114.crv (Δp = 115.6 mm b)

λ_{SH1}	E_{SH1+b}	b	E_{SH1}	λ_{SH1}	E_{SH1+b}	b	E_{SH1}
776.3	60.5	1	59.5	980	27.9	4.4	23.5
780	58.8	0.9	51.9	1000	25.5	4.7	20.8
790	54.4	0.9	53.5	1020	25.4	7.1	18.3
800	51.6	0.9	50.7	1040	25.8	10.4	15.4
820	48.7	1.0	47.7	1060	25.0	12.1	12.9
840	47.2	1.2	46.0	1080	26.2	14.3	11.3
860	42.7	1.5	41.2	1100	34.7	26	8.7
880	39.0	2.0	37.0				
900	35.7	2.4	33.3				
920	34.1	4.5	29.6				
940	32.4	5.7	26.7				
960	31	5.5	25.5				

SHS774.crv

λ_{SHS}	E_{SHS+b}	b	E_{SHS}	λ_{SHS}	E_{SHS+b}	b	E_{SHS}
550	39	2	37	680	70	7	63
560	52	3	49	690	70	8	62
570	63	3	60	700	69	9	60
580	70	2.5	67.5	710	72	10	62
590	71	2.5	68.5	720	72	10	62
600	72.7	4	68.7	730	71	9	62
610	77.5	5	72.5	740	69	8	61
620	79	6	73	750	62	2	60
630	75	5	70	760	62	1	61
640	74	4	70	770	62	1	61
650	71	4	67	775	59	1	58
660	71	5	66				
670	72	6	66				

516.933
517.222

SF774.crv

λ_{SF}	E_{SF+b}	b	E_{SF}	λ_{SF}	E_{SF+b}	b	E_{SF}
455	82.5	6	76.5	525	43	8	35
460	101	6	95	530	45	6	39
465	118	8	110	535	44.7	6	38.7
470	116	11	105	540	45	6	39
475	110	8	102	545	45	8	37
480	104	10	94	550	48	10	38
485	97	11	86	555	49	10	39
490	93	10	83	560	52	10	42
495	86	7	79	565	56	8	48
500	84	6	78	570	61	7	54
505	82	7	75				
510	77	8	69				
515	83	9	74				
SF5 ↑ 516.93	83	10	73				
516.933	83	10	73				
SF1 ↓ 517.204	52	9	43				
520	49.7	9	40.7				

λ_{DF}	E_{DF+b}	b	E_{DF}
2600	25.0	18.2	6.8
2500	21.8	14.2	7.6
5000	18.1	10.0	8.1
3200	15.5	7.5	5.0
3400	12.7	5.9	6.8
3600	11.2	4.6	6.6
3800	10.2	3.8	6.4
4000	8.9	3.3	5.6
4200	7.5	2.9	4.6
4400	7.6	2.6	5.0
4600	7.1	2.3	4.8
4800	6.4	2.2	4.2
5000	5.8	2.0	3.8
5500	4.6	1.5	3.1
6000	3.7	1.14	2.56
6500	3.0	0.97	2.03
7000	3.0	0.87	2.13
7500	3.05	0.83	2.22
8000	3.01	0.79	2.22
8500	2.78	0.78	2.00
9000	2.52	0.78	1.74
9500	2.37	0.81	1.56
10000	2.31	0.83	1.48
10500	2.25	0.86	1.39
11000	2.15	0.88	1.27
11500	2.06	0.94	1.12
12000	1.96	0.97	0.99
12500	1.85	1.05	0.80
13000	1.73	1.09	0.64

DF2774.crv (Case)

λ_{DF}	E_{DF+b}	b	E_{DF}
4500	6.65	1.60	5.05
5000	5.60	1.30	4.30
5500	4.60	1.1	3.50
6000	3.75	0.83	2.92
6500	3.10	0.74	2.36
7000	3.00	0.69	2.31
7500	3.07	0.69	2.38
8000	3.07	0.65	2.42
8500	2.88	0.61	2.27
9000	2.65	0.62	2.03
9500	2.50	0.62	1.88
10000	2.40	0.61	1.79
11000	2.27	0.63	1.64
12000	2.22	0.70	1.52
13000	2.18	0.76	1.42
14000	2.12	0.82	1.30
16000	1.95	0.89	1.06
18000	1.76	0.91	0.85
20000	1.54	0.93	0.61
22000	1.36	0.93	0.43
24000	1.21	0.92	0.29
26000	1.09	0.89	0.20

3T Magnet

TOPAS 4/800 ALIGNMENT GUIDE

Introduction

This guide is aimed to enhance the TOPAS user's manual by providing the user with alignment instructions specific for TOPAS4/800 (5-pass TOPAS version pumped by the fudamental harmonic of a pico/femto Ti:sapphire amplifire). It assumes that the TOPAS has been installed by a service engineer approved by the manufacture. It also assumes that the user knows the basics of optical parametric amplification and has medium to high level of experience in the field of experimental ultrashort-pulse laser optics.

Part I of this guide gives the main procedures required for usual day-by-day operation of the TOPAS. ***Part II*** describes the TOPAS setup and gives a detailed picture of how the TOPAS alignment should look-like in order for the device to function properly. ***Part III*** covers TOPAS diagnostics and realignment procedures in case ***Part I*** procedures cannot restore the specified or usual TOPAS output. Please, read ***Part II*** before proceeding with ***Part III***. Finally, ***Part IV*** describes the TOPAS recalibration procedure that may be required after the realignment has been done.

Note 1: If you are in doubt of any action or procedure described here please contact our service team for more advice before acting on TOPAS.

Note 2: The user is kept responsible for any damaged to TOPAS optics or/and mechanics, which occurred during the TOPAS alignment by the user.

We would like to thank our TOPAS user Daniel-Steve Fournier from University of Toronto, who compiled "TOPAS FINE ALIGNMENT PROCEDURE", which was used as a basis of this guide.

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I. Day-by-Day TOPAS alignment

1. Warm-up the TOPAS pump laser and do day by day checking/ adjustment procedures recommended by the laser manufacture. Check the TOPAS input energy to correspond the specified/ usual value. 1 hour warm up

2. Start the TOPAS software WINTOPAS and tune the TOPAS to a checkpoint wavelength(s). Check the TOPAS output energy at that (those) wavelength(s) to correspond the specified/ usual value.

① 1.3μM w/o Crystal = 209 mW

② 900nm
power = 33.3 mW

3. If the TOPAS output energy at checkpoint wavelength(s) is lower the specified/ usual values with good input energy, check the Signal+ Idler (S+I) energy with no mixing crystals involved to correspond specified/ usual values.

4. If S+I output is OK, reset a Mixer(s), which produced lower output. Measure a new Mixer offset if needed.

5. If S+I output is low, try to restore the output energy by fine adjustment of the pump beam steering mirror closest to the TOPAS input.

6. If S+I output is low after the fine adjustment of the input mirror, reset the TOPAS motors.

Inj → horizontal: 1st 3rd beam path in front of small dielectric mirror should be in the same line
→ vertical: 3rd beam should go thru slit w/ bluish superfluence

7. If all above does not help to get specified/ usual TOPAS output, proceed to the TOPAS diagnostics and realignment section (Part III), which will help you to detect and fix the problem. Part II is recommended to read before starting with part III.

8. - DFG depends on overlap btw S & i
→ Need to change M7/M8 for overlap in MIR
- DFG may vary w/ Iris opening on L6
- 1114 is most recent file as of Apr. 03

II. Understanding the TOPAS

At this stage, we want to give a detailed feeling to the reader about what's going on at each stage of the TOPAS. An alignment procedure will follow at the next section.

First, second and third passes: the seed beam

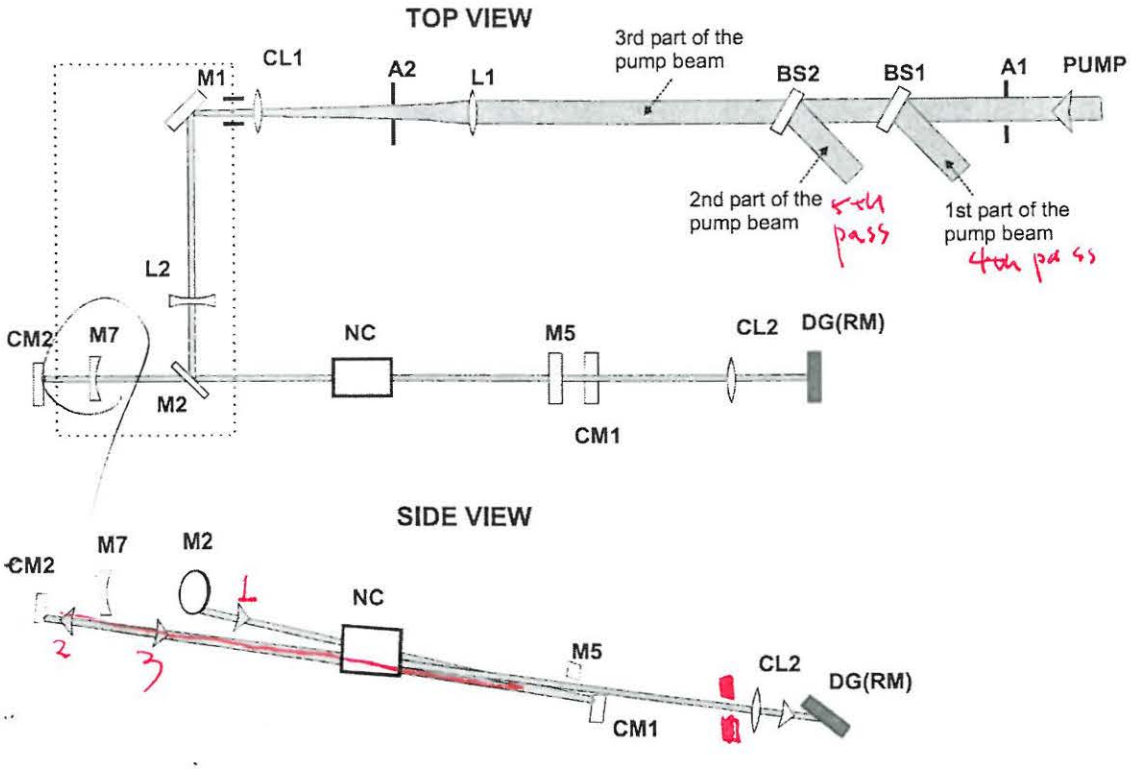


Fig. 1: Top view and side view layout of the first, second and third passes beam paths inside the TOPAS.

1. The pump beam is split into three components upon entering the TOPAS. The first two are going to be used for the fourth and fifth passes (amplification). The third component is the light that passes through BS1 and BS2 to be reflected by the main assembly towards the nonlinear crystal (NC) and is referred as the first pump that generates parametric superfluorescence (SFL) or seed light inside the TOPAS. This latter component of the light will do in total three passes in the NC, which they will be called respectively the first, second and third passes. 1-3rd passes use both spherical (L1, L2) and cylindrical (CL1, CL2, CM1, CM2) optics to shape the beam, thus it is normal that the beams have no spherical symmetry in the 1-3rd passes.

2. The first pass goes from the lower edge of M2 to the upper part of CM1. That first pass is pumping the NC in order to produce SFL.

3. The second pass is the backward reflection from CM1, through the NC, up to CM2. This second pass amplifies the collinear components of SFL produced in the first pass.

4. The third pass is the reflection from CM2 through the NC to the diffraction grating (DG). The third pass passes just above CM1 to that it can reach the DG. The third pass amplifies the second pass output. The first three passes do not overlap in space but are in the same vertical plane. At CM1, the 3rd pass should be right above the 1st pass and the 2nd pass must be in the same phase-matching plane as the first one (remember, the second pass beam spot is visible only before CM2 or before the main assembly if one keeps a paper-card low enough not to block the first pass).

5. TOPAS pumped by ~800nm light generates IR wavelengths (signal and idler) in the range of ~1.1-3um, which is not visible to human eye, however same IR wavelengths get mixed with the pump in the same NC and produce week visible output. Thus one can see a visible beam (e.g. green when signal is set to ~ 1500 nm or reddish when signal is set to ~ 1200 nm) on top of the pump starting from the second pass (the first pass is usually to week to be seen). The visible light follows approximately the same path as the true signal and ilder beams and can be used as guidance in TOPAS alignment and as an indication of parametric conversion.

6. Notice that the third pass will pass in the slit before CL2 to ensure a proper alignment on the DG. Then, it will hit the center (axis of rotation) of the DG. The spectrum of the signal beam will then be diffracted (spread) spatially (ref. fig. 2) while reflected back through M5 to the crystal. This will become the fourth pass when the second part of the pump will be applied (ref. fig. 1). Idler and the pump reflected from the grating will not be used further.

Fourth pass: pre-amplification of the seed beam.

At this point, we basically have a seed beam, relatively weak, with a spectrum that is reflected on the crystal. This seed beam will be pre-amplified by the fourth pass pump beam. Since the fourth pass pump beam is focused to a smaller beam, only a narrower spectrum of the diffracted beam will be amplified.

Notice that the purpose of the grating is to narrow the spectrum (together with the 4th pass, see principle on fig. 2), to separate signal, idler and pump in space and to make wavelength tunning easier close to NC absorption band. Notice also that VIS light, seen during parametric superfluorescence/amplification is combination of harmonics and sum-frequencies (p+s, p+i, shs,…) non-phase-matched generated in the same NC.

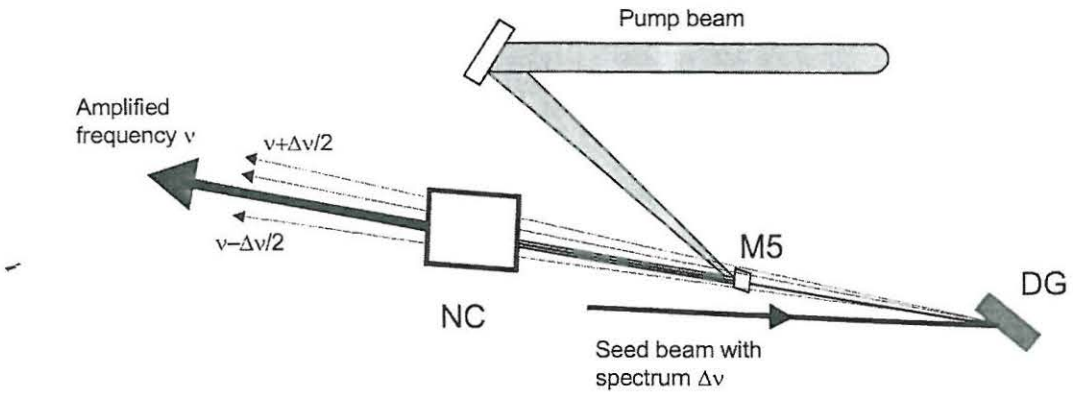


Fig. 2: Scheme showing the principle of the pre-amplification in the fourth pass. The spectrum of the seed beam (1-2-3 passes) is spread on the crystal, reflected from the DG. Then, the fourth pass pump beam comes to overlap on the crystal, but only on a narrow area, corresponding to a narrower bandwidth of the seed beam, depending on the phase matching condition between the seed and the pump.

1. $T_{BS1}xR_{BS2}$ of the incoming pump beam is used for the fourth pass. First, it is focused by the zoom-telescope (by passing through L3', L3 and L4) in order to be able to select a narrower bandwidth (BW) and to have enough intensity to amplify the seed. This pump beam acts as pre-amplification only, since the energy is low (but intense enough due to the small spot on the crystal). *Once the fourth pass will have selected a BW of the seed by pre-amplification of it, then will come the fifth pass, with higher power, bigger beam size, to amplify that BW to the final output power level required.*

2. The fourth pass pump beam then traverses a fused silica plate (GP) that compensates for the lateral drift of the first three passes introduced when crystal changes its angle

(to ensure that the pump beam hits the mirror M5 always at the same spot as the seed).

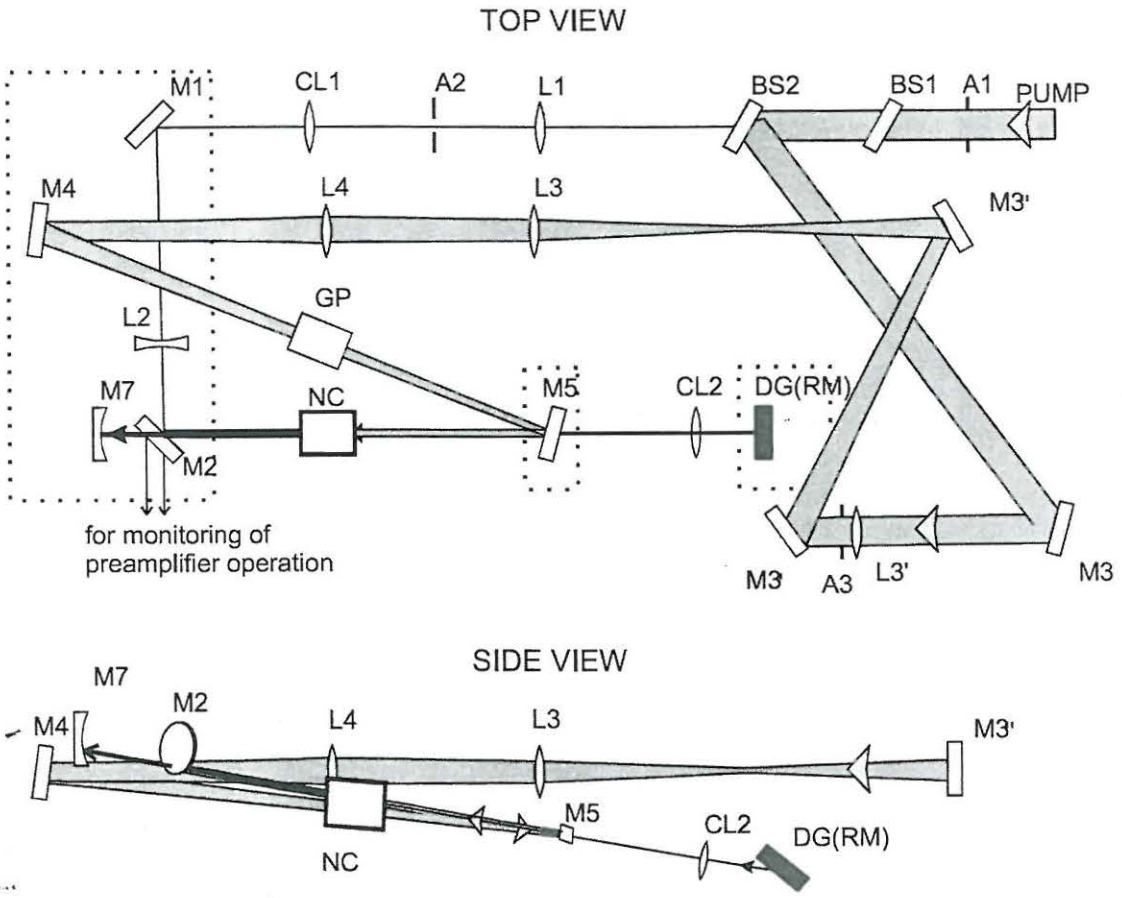


Fig. 3: Top view and side view layout of the fourth pass light path inside the TOPAS.

3. Then, M5 reflects the pump towards the NC. The seed light (signal) reflected from the DG goes through M5 to meet the pump at the front surface (the surface overlooking the NC) of M5. The DG is mounted on a delay stage so that one could adjust the delay between the seed pulse and the pump pulse so that they can overlap not only in space, but also in time. This is the DELAY 1 adjustment. It is adjusted only when the 4th pass alignment is changed. It must be adjusted at zero order of the DG.

4. Then, the small beam spot hits the NC and amplifies the appropriate WL depending on the angle of the DG and of the NC. DG must reflect collinear components of the signal, generated/amplified in NC.

5. Then, the pre-amplified seed beam goes through M2 where the pump is reflected (filters the pump light @ ~800nm) and the seed is reflected by M7 (Al focusing mirror). Then, the cleaned seed beam goes back ABOVE the crystal, THROUGH time delay plate (TD) and ABOVE M5 to hit M8. This time the beam is passing TD crystal for separation of signal and idler in time. A bright visible spot is seen in front of TD as an indication of preamplifiction in the 4th pass. The spot should disappear if either of pump or seed (1-3rd passes) is blocked. Alternatively, two bright visible spots can be seen going away from M2 (called "for monitoring of preamp op" in fig 3).

Fifth pass: final amplification.

At this point, we have a seed beam that has been pre-amplified by the fourth pass and that the spectrum has been narrowed by use of the diffraction grating spreading in combination with the spot size of the pump beam in the fourth pass. This seed will be amplified to its final power level in the 5th pass by using most (R_{BS1}) of the incoming pump beam from the pump laser.

1. R_{BS1} of the incoming pump from the laser is used in the fifth pass. The beam is collimated to a beam spot size that will have intensity for saturation of amplification in the 5th pass. This is in order to maximize the amplification in the crystal, but yet, not to overpump (the beam, pulse and spectrum get distorted) the crystal by having a reasonable intensity.

Notice here that before L5 and L6 that act as telescope objective (collimate the beam), the pump beam pass by the mirror M10 mounted on a delay stage. Again, as in the fourth pass, this delay (so-called DELAY 2) will be use to overlap in time the seed beam from the first four passes with the pump beam of the fifth pass.

Notice also that from M11 to the output, the fifth pump beam path should be collinear with the fourth pass seed path and both beams must stay in phase-matching plane used in first four passes.

2. Then, both the pump and the seed pass go through the crystal. Because of the high intensity, parametric amplification occurs, according to the angle of the crystal.

3. Then, the pump beam is blocked at the output (by M12) and the signal and idler come out. The mixer I and/or II can be combined to produce SHG of both idler and signal, sum-frequency, higher harmonics or difference-frequency.

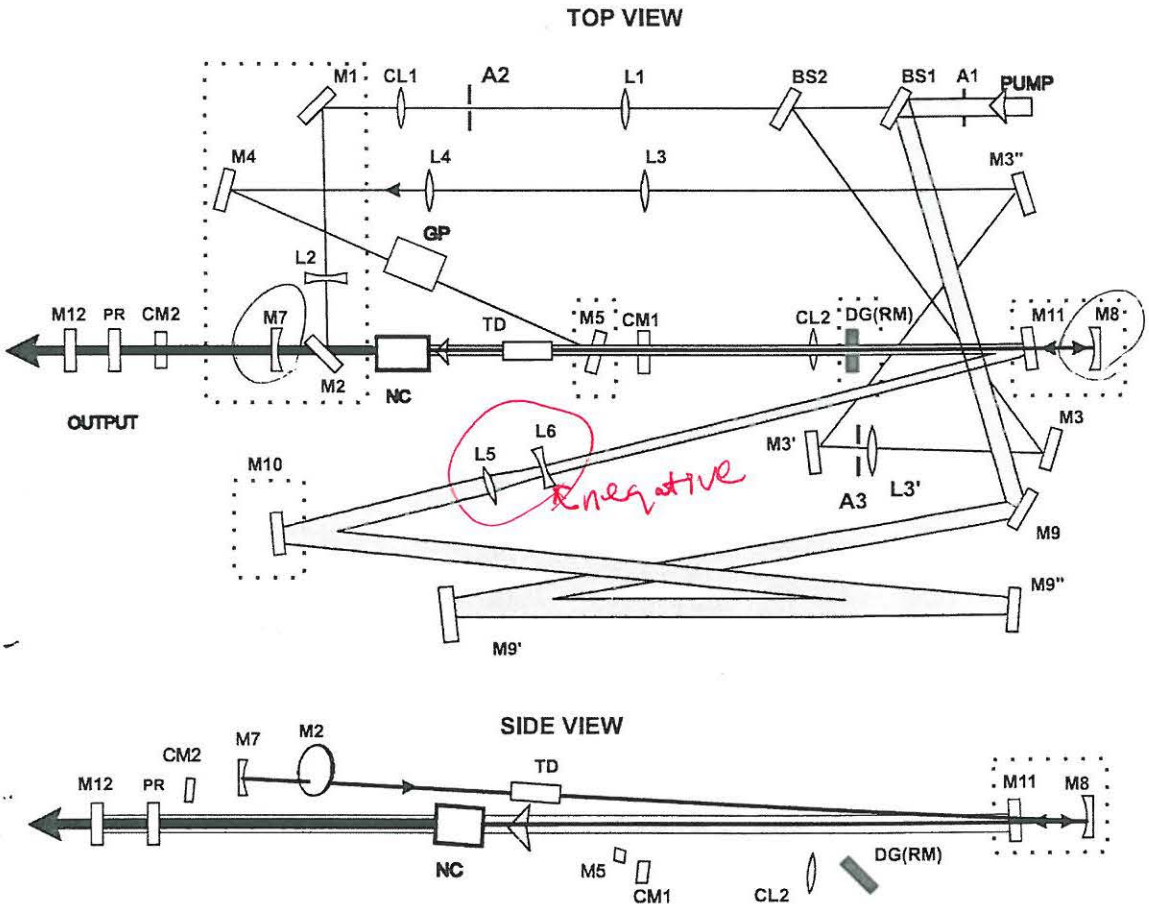


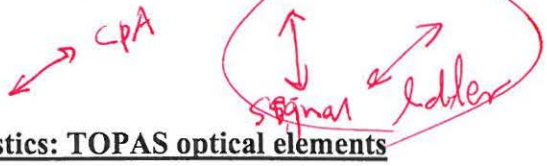
Fig. 4: Top view and side view layout of the fifth pass light path inside the TOPAS.

III. TOPAS diagnostics and alignment

This procedure contains two major steps. The first step is a verification procedure. No optical elements should be touched. This is only a diagnostic procedure. Some external mirrors may be tweaked, but NOTHING INSIDE THE TOPAS SHOULD BE TOUCHED.

Diagnostics: pump beam and pulse parameters

1. Check the pump laser performance and the TOPAS pump beam parameters such as energy, pulse duration, beam quality to correspond the specified values. The laser power should be approx. _____ W, pulse at _____Hz, _____fs duration, beam profile _____. If possible, check the contrast ratio of the pump pulse, using a fast photodiode. The contrast ratio should be > 1/100 (or 100, depending on convention). Pump polarization for TOPAS must be horizontal.



Diagnostics: TOPAS optical elements

2. If the pump is OK, check the TOPAS optical elements (especially the main BBO crystal) for possible damage.

Diagnostics: TOPAS alignment

3. If everything is OK, check the TOPAS alignment:

   a) Reset all TOPAS motors if not done yet (unnecessary reset is not recommended). Set the signal WL to ~1300 nm.

   b) (ALL PUMP PASSES BLOCKED) Check that the input beam is centered on the input aperture A1.

c) Check that the beam in the first three passes and the fourth pass are in one vertical plane. To do so, check the third and first passes by placing a card before CM1. By scanning in height of the card, one could see the first and third pass alternatively and verify their alignment. (FOURTH PUMP PASS UNBLOCKED) The fourth and the first passes could be checked by placing a card before the NC (between NC and M5).

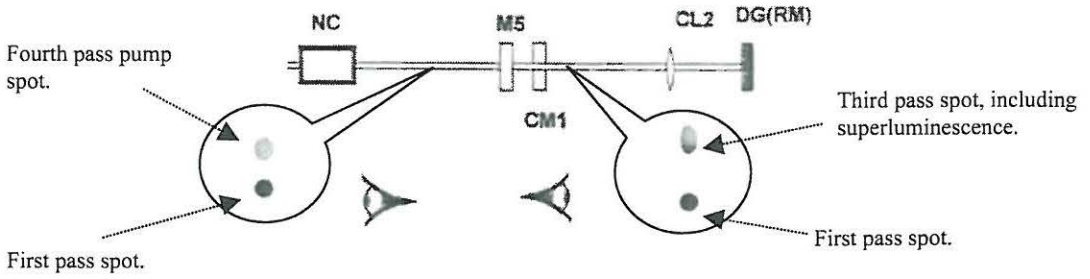


Fig. 5: Views of the beam spot configuration on the card when checking for the first, second, third and fourth passes.

d) (4^{TH}, 5^{TH} PASS PUMPS BLOCKED) Check that the third pass beam is just above of the first pass beam and goes right through the horizontal slit of CL2 holder.

e) (4^{TH}, 5^{TH} PASS PUMPS BLOCKED) Check that you get parametric SFL signal after the third pass (one should see some visible light on top of the 800 nm light). Look on a white card before CL2. SFL (VIS light) must be strong and stable. Notice that SFL is more divergent in vertical plane.

f) (5^{TH} PASS PUMP BLOCKED) Check that you get amplification in the fourth pass (one should see two bright visible blue (non-phase matched SH of pump) and green-yellow (non-phase matched sum-frequency of pump and SFL) spots going away from the main assembly towards M10). Likewise, one could see an intense visible beam (from signal&idler sum frequency with the pump) when placed a card before TD (beam coming from above NC).

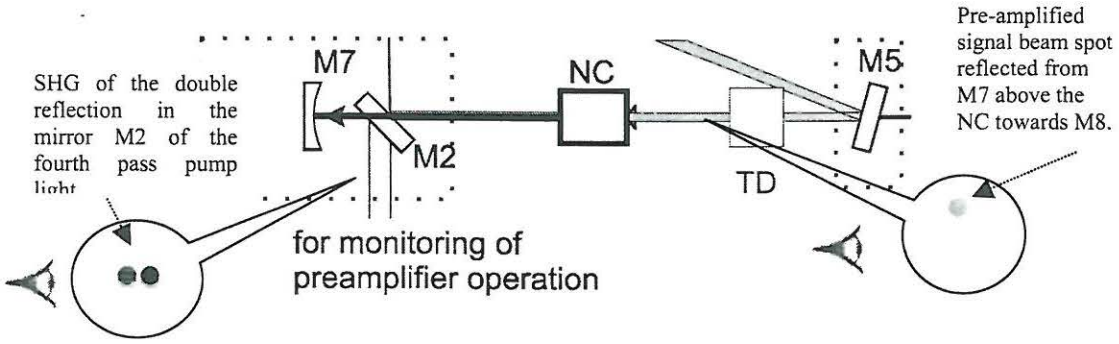


Fig. 6: Views of the beam spot configurations on the card when checking for the pre-amplification at the fourth pass.

g) (ALL PUMPS UNBLOCKED) Check that the pump beam and the seed beam are collinear in the fifth pass. To do so, one could first check if the fifth pass pump overlaps with the seed on M11 (place a card in front of M11, block and unblock alternatively the 5th pump and see if the spots on the card overlap in space. Use goggle at 800 nm to see the SHG of the pump, which is weaker and easier to see). Second, one could check the same overlapping, but this time, at the output of the TOPAS (open pump blocking mirror M12 or use week SH of the pump). Set signal WL to 1300 nm and use SH generator to visualize the signal at the TOPAS output.

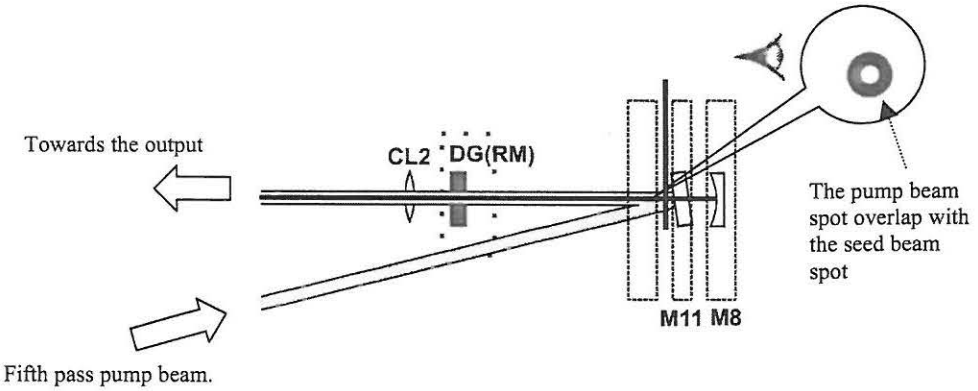


Fig. 7: Views of the beam spot configurations on the card when checking for the fifth pass overlapping with the seed.

Try to restore the alignment by tweaking **just the external beam rooting mirrors**. If that is not possible, refer to the next section that describes more detailed realignment procedure of the TOPAS.

THE SECOND MAJOR STEP IS THE REALIGNMENT PROCEDURE ITSELF. IN THAT CASE, OPTICS INSIDE WILL NEED TO BE ADJUSTED AND THEREFORE, A RECALIBRATION OF THE TOPAS MAYBE NECESSARY TO BE PERFORMED. THIS PROCEDURE IS FOR TRAINED PERSONS ONLY AND SHOULD REQUIRE A LOT OF ATTENTION AND UNDERSTANDING.

Realignment: First, Second and Third passes: seed signal

Align the first three passes using the external mirrors:

a) Check that the input beam is centered on the input aperture A1 and aperture A2.

Notice that if one touches the input mirror, the aperture A1 and A2 should be set so that, once the first three passes aligned, the beam passes in the middle (center the apertures) of A1 and A2.

b) Check that all three passes are in the same vertical plane. It is convenient to check the beam positions at CM1 mirror: the beam after the third pass (that goes just above the mirror) should be right above the first pass beam (that strikes the top edge of CM1). See fig.5.

Notice that if one wants to align the TOPAS at a different signal WL, by turning manually the crystal (using the appropriate knob, see fig. 11), it is possible to change the color of the superluminescence seed (e.g. for signal at 1500 nm ~ green, at 1600 nm ~ yellow, at 1300 nm ~ purple).

c) If you cannot see the 3rd pass beam, check that the second pass hits the mirror CM2 (use paper card). If one cannot hit CM2 using the external mirror, try to adjust the tilt of the CM1 using a hexagonal (2 mm) key.

d) Check that the third pass beam goes right through the horizontal slit of CL2 holder. If the third pass is too high or too low, one could try, first to align the external mirror to get the first three passes aligned, but if even once aligned, the third pass does not go through the slit, one could then adjust the tilt of CM2 using hexagonal (2 mm) key.

Notice that the beam at the third pass should be vertically stretched since it passed through cylindrical mirrors (CM1 and CM2), cylindrical lens CL1 and is focused in the crystal to a horizontal line.

e) Check that when the aperture A2 is closed (or smaller diameter), the visible SFL signal goes away. This is due to the fact that by closing the A2, the power in the crystal drops (energy goes down and beam diameter increases in focal point) and the power is no longer high enough to produce SFL.

f) If you cannot get any visible light after the third pass with A2 fully opened, it may be the indication that the pump laser is not working properly. Proceed further only after making sure that the pump is OK and that the first TOPAS passes have no damaged optics including the NC. Indication of damage is scattered pump beam and/or strong white-light (continuum) generation. Also check that the NC position is OK. Reset the crystal if not sure.

g) If everything is OK and still no visible light can be detected after the third pass, try to move the lens L1 to get a higher intensity in the crystal and brighter visible light after the third pass (different divergence might require repositioning of L1. Note: No superfluorescence with the same pump divergence would indicate in decreased pump intensity- longer pulse duration in focal point, smaller energy or lower contrast. One has to check laser before proceeding further). Mark the beam position in front of CL2 before unscrewing L1, and try to maintain the same position when moving. Go through this

section once more to check the first-third passes after securing the L1. The goal is to achieve strong and stable SFL after three passes.

h) Move BBO crystal of TOPAS to the highest possible position. SFL should not become weaker because of beam (2^{nd} pass) clipping.

FOR MORE DETAILED INFORMATION REFER TO THE TOPAS USER'S MANUAL SECTION 3.4 FIRST, SECOND AND THIRD PASS ALIGNMENT.

Realignment: Fourth pass: pre-amplification of the seed.

At this point, the first three passes should be aligned. So, the external beam routing mirror should not be touched anymore, unless it is for very fine optimization later on. Remember that the third pass should already have SFL signal generated only with the power contained in the first three passes. Now, we have to make sure that the seed reflected from the grating collinearly overlaps spatially with the pump in the fourth pass and adjust the time overlap between the pump and seed pulses if needed. Then, with the fourth pass, we will pre-amplify a part of the spectrum of this seed signal using a part of the incoming pump $T_{BS1}xR_{BS2}$ from pump laser. Refer to the part II for more general explanations.

Here, for convenience purpose, the procedure assumes that the TOPAS is set to a signal close to 1500 nm (reset motors if any has been touched by hand). So, the SFL signal should be green (to be more exact, SFL signal is in IR, however it produces some green-yellow-red when mixed with the pump in the same nonlinear crystal).

a) First, make sure that the pump beam is not clipped anywhere from BS2 up to the crystal (except of A3). Make sure that the beam is centered on the aperture A3. If it is not, one can adjust the tilt of the BS2 by adjusting the top hexagonal screw and by tilting slightly the beamsplitter adapter.

b) Observe two spots going away from the main assembly towards M10 (side reflection of M2). Since both the pre-amplified seed and the pump are passing through M2, the spots should be composed of SH of the pump (blue spots at ~400 nm) and some seed green light (when at 1500 nm) (see fig. 6). If you see no green even with A3 fully opened that means that there is no amplification. If you have amplification, go to Realignment: Fifth pass: final-amplification of the seed. Likewise, one could see an intense visible beam (from non-phase-matched signal & idler sum-frequency with the pump) when placed a card after TD crystal (beam coming from above NL crystal). Checking of beam after TD is convenient for overlapping of pump and signal reflected from diffraction grating (DG) (at zero order); and for optimization of pump intensity in 4^{th} pass. One should not see any SFL when the seed beam after BS2 is blocked.

c) One way to align the fourth pass is to use the zero order diffraction from the DG. That means that instead of reflecting seed at the second or higher order with a particular angle, the seed is reflected at 0 angle.

i. **(For picosecond TOPAS only!)** First, block the fourth and fifth pass pump beam before M3 and M9. Then mark the grating holder (moving part) position with respect to its sleeve (still part). Then, unscrew the screw **S1** (using hexagonal key) on the side of the grating (ref. fig.8) and tilt manually the grating to approx normal incidence to the third pass. *Notice that in fs-TOPAS version grating rotation stage reaches 0 angle and working angle (no need for manual rotation and unscrewing of S1). Just rotate the grating to 0 position by using the software.*

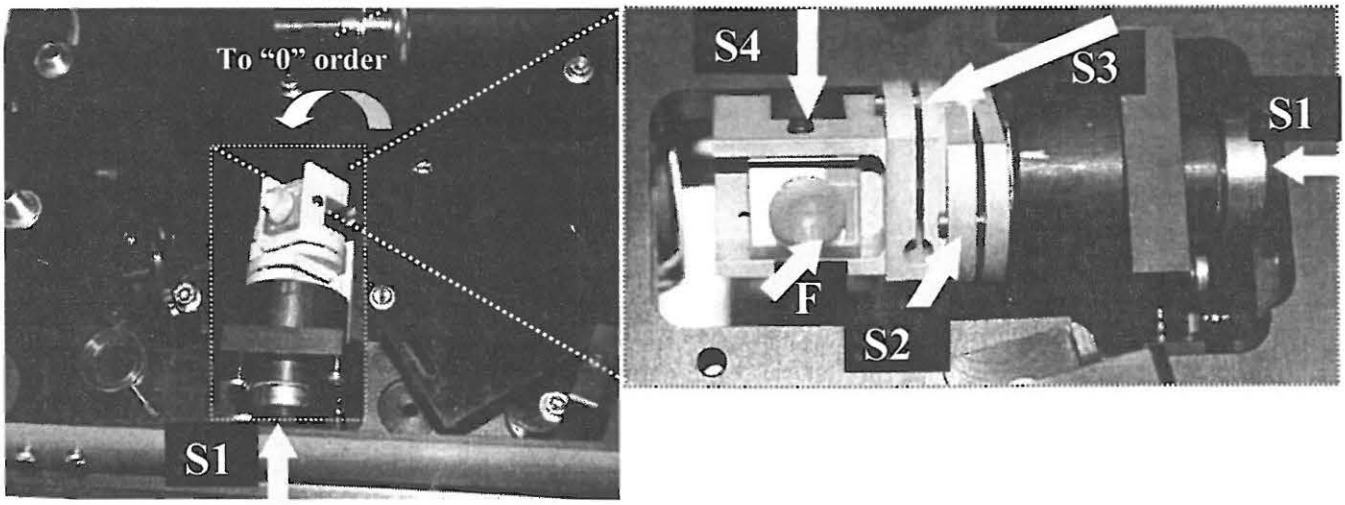


Fig. 8: Views of the diffraction grating holder and the position of the screw we have to release in order to be able to set manually the 0 order of the DG. Notice that on this picture, the grating angle is NOT at the 0 order position, but the direction of the rotation is shown.

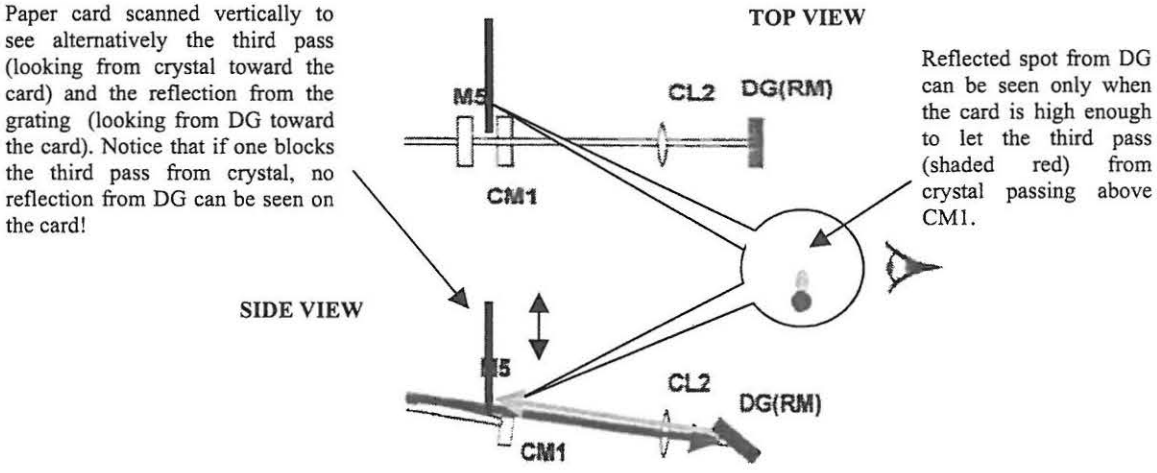


Fig. 9 Views of the beam spot configurations on the card when checking for the reflected third pass from the DG in order to align the fourth pass.

ii. Then, fine adjust the grating angle using the knob (see fig. 11) to get green light reflected above CM1 on a card placed just above the third pass spot in front of M5.

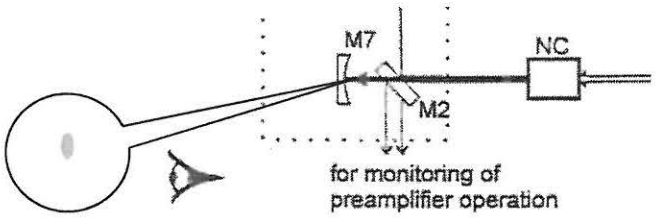
Notice that by touching the grating screw S1 *(ref. fig. 8), one will loose the calibration of the grating. Therefore, a calibration will have to be performed after alignment.*

iii. Then, make sure the reflected seed from the grating is in the same vertical plane as the third pass. One can adjust the horizontal alignment by adjusting **S2** (ref. fig.8).

Notice that the reflected beam from grating passes through the mirror M5 where the pump at 800 nm is blocked and only the green-yellow light is going through the crystal.

iv. Then, make sure that the reflected seed beam pass above CM1 (step i), through M5, in the crystal (on the top part) and hits the mirror M7 (see fig. 10). If one cannot see the beam on M7 (when pump is blocked), a vertical alignment of the reflected beam at the grating is possible using the grating angle knob (ref. fig.11). Also, one can see the seed beam in front of the main assembly just above the first pass. **Make sure the seed passes through nonlinear crystal, not above.**

Fig.10: View of the beam spot configuration on the card when checking for the reflected 0 order third pass from the DG on M7 (4TH AND 5TH PUMPS BLOCKED).



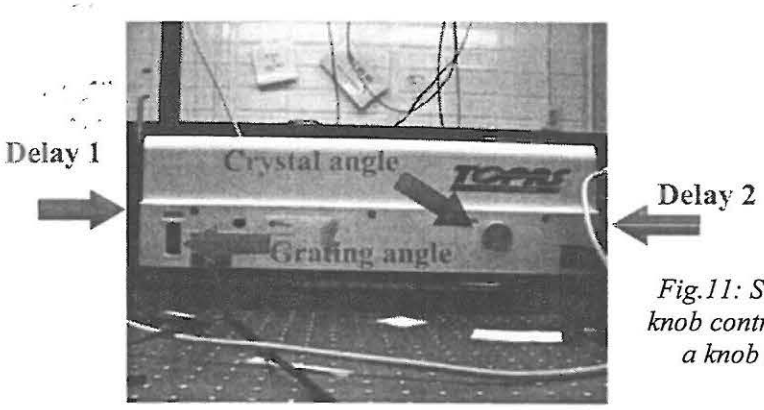


Fig.11: Side view of the TOPAS box. There is a knob controlling the angle of the crystal and also a knob controlling the angle of the grating.

v. Also, check that the fourth pass pump beam passes through the fused silica plate GP, hits M5 and is reflected on the crystal, in the same vertical plane as the 4th pass seed.

vi. Now that the seed beam goes up to M7, let's spatially overlap the pump beam with the seed. Place a paper card before the crystal, and check that the pump beam is in the same vertical plane as the green seed and the second pass beam spots. Ultimately, we want to overlap the pump beam (blue spot on the card using goggle @ 800nm, since blue ~ SHG of 800 nm) with the green seed beam. Move M4 to adjust the height of the pump beam, and move M5 to adjust the tilt (horizontal displacement). Verify that the overlapping occurs before and after the crystal (ref. fig.

12). Use the largest possible distance between checking points. To verify the overlapping, block alternatively (ON/OFF) the pump beam before M3 to see green and then the blue overlapping the green spot.

The overlapping of the pump (intense) and the seed is easier using the goggle @ 800 nm that allows to see the SHG (blue spot less intense) as well as the seed beam at ~ green.

A verification point is before M2, where, when the card is place high enough, will see the vertical alignment of the seed and the pump. When the card is lower, one will see the first pass beam (have to scan the card in height to see second pass, and therefore, disabling the fourth pass).

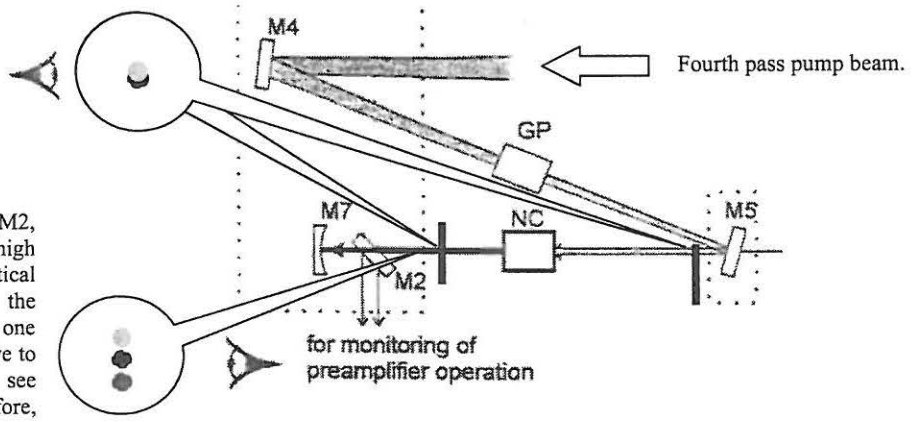


Fig.12: Views of the beam spot configuration on the card when checking for the overlapping of the fourth pass pump beam and the seed beam before and after the crystal. Also, a view of pump and seed alignment in the same vertical plane.

Notice that by overlapping the pump and the seed immediately before and after the crystal will approximately overlap the two beams WITHIN the crystal. Then, we will optimize the overlapping by fine adjustment later.

d) Now that we have an approximately good spatial overlapping, place a card in front of the M5 so that one could see the fourth pass reflected from M7 and coming from above the crystal. Then, adjust the delay 1 knob (ref. fig. 11) so that the intensity of the seed green spot on the card is maximized. The delay 1 will overlap in time the pulses of the pump with the pulses of the seed. Fine adjustment of Delay 1 can be done by measuring energy of pre-amplified seed and monitoring the SHS beam.

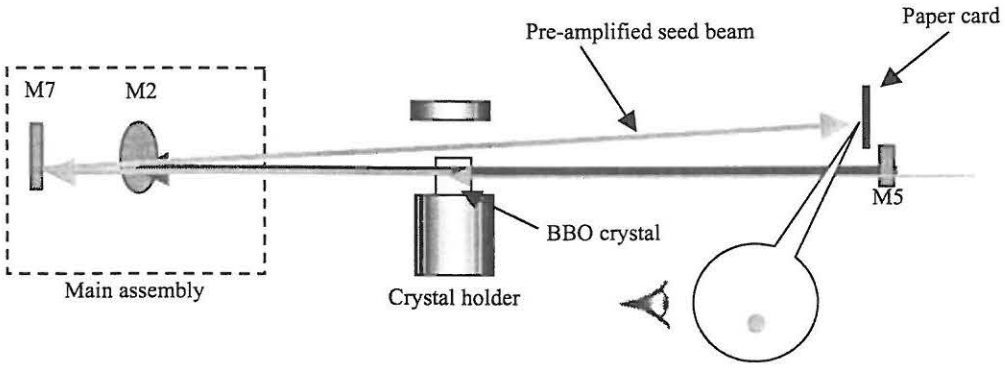


Fig.13: Side view of the fourth pass trajectories for the pump and the seed. The pre-amplified seed beam is viewed on a card place after TD2 and is used to maximize the overlapping.

Notice that the blue-green-yellow spots on the side of the main assembly (side of M10, on the card) should therefore be maximized once the time and spatial overlapping is adjusted.
Notice that the pump intensity in the fourth pass must be below the threshold of superfluorescence when the seed is blocked. The superfluorescence may be easily detected just after NL crystal or after reflection from M7 and passing TD. Superfluorescence will have much bigger beam diameter of VIS (yellow-green-reddish) light than the amplified beam. Generation of supercontinuum (colored concentric rings) indicates that the pump intensity is much too high. Close A3 to reduce the intensity.

e) Now when we have the 4th pass working with the grating in the 0 order, the following step is to get the grating back to the working order.

For picosecond TOPAS only: Reset the grating motor. Unscrew the screw S1 and tilt the grating face down and match the marks that should have been made before releasing the screw for the first time [this will ensure that one catches at least the same order as that before the readjustment]. If you don't have any marks, follow the grating calibration procedure in the TOPAS manual.

For femtosecond TOPAS: Just set a working angle (usually the second order of the signal) of the grating (a table with the grating angles vs wavelength can be found in TOPAS manual) in TOPAS control software.

Realignment: Fifth pass: final-amplification of the seed.

Now that the first four passes are aligned, we will need to get a visible output to maximize the overlapping in the fourth pass and to align the fifth pass. Therefore, we need to set the TOPAS to a signal WL that will produce a visible light once at the output of the mixer 1.

a) Set the TOPAS to 1300 nm*. Block the fifth pump before M9, insert a white card in front of M11 and observe the visible spot that comes from M7. If you can see three visible spots (yellow, blue, red) in a row, the beams are slightly not collinear in the fourth pass. Tweak M5 to overlap all the spots.

* If the grating has been set to the 0 order and back using the screw **S1** (see fig. 8), its position may not be exact, so tune the grating (use "direct access" window of Wintopas) to maximize the 4th pass energy after setting the wavelength.

b) Now try to get the fourth pass beam at the TOPAS output (adjust M7 and M8). Double the signal with the crystal #2 of the mixer 1 (make sure that the orientation of the mixer is appropriate for the generation of second harmonic of signal - SHS). You should get a week red spot. The intensity of the spot should change when adjusting A3. Close A3 to the point where you don't see any halo around the main beam. The spot may get distorted when you open A3 too much.

c) Now, we will adjust the fifth pass. The goal is to make the fifth pass beams collinear and overlapping in time with the 4th pass. Check that the fifth pass pump is passing in the middle of the optics. Check that the fifth pass pump is collimated; adjust L6 if needed (to get a beam that will stay collimated several meters after TOPAS). You should not see any parametric light generated in the fifth pass, when the first passes are blocked. Check that the fifth pass pump beam is parallel to the beams in the first passes and goes through the center of the crystal (adjust M10 and M11 if needed).

λ	crystal	Step	deg	Step	mW	Bg
6.4 μm		5	20.513	6837	3.1	~~0.55~~
〃	crystal	5	20.4[illegible]	6812	3.39	0.55
		(Mixer 2 changed)				
2 μm	〃					
2 μm	〃	22.190	crystal/Amp./Mix I Maximized		2.3	0.8d ⇒ 1.[illegible]
			Original		1.404	

d) Overlap the seed beam (fourth pass) with the pump on M11. To do so, block the pump and look on the card before M11 to see the 4th pass seed spot (see fig. 7 for the position of the card). Then, unblock the pump and check the overlapping of the pump with the seed. Adjust M7 to optimize the overlapping visually. *Note, that position of VIS light generated in the main crystal of TOPAS does not overlap exactly with signal. The best is to check overlapping of SHS of seed and SH of pump after external SH crystal.*

Notice that we want to align the fourth pass with the fifth pass and not the fifth pass with the fourth pass. In other words, we fix the fifth pump and we adjust the fourth pass seed beam.

e) The second step to optimize the spatial overlapping is to check at 1-10 m distance away from the TOPAS (usually one can see a week blue spot that is SH of the pump and overlap it with the red spot- SH of the signal). Move Delay 2 (use amplifier slide bar in "direct Access" window of Wintopas) to get rid of the amplification in the 5th pass if you have any. Adjust M8 to maximize the overlapping.

Notice that two knobs at the back of M8-M11 assembly (closer to the TOPAS front panel) control the mirror M8 only, but the front knobs adjust both mirrors.

f) One of the most sensitive methods of alignment of pump and signal in the last pass is to check overlapping of pump and SH of signal just at the SH crystal and in far field (2- 10 m) from the TOPAS. One can use week blue light for monitoring of position of pump. Delay between pump and signal (amplifier delay, motor #2) should be misaligned (pump delay is better decreased) when aligning the fifth pass. It is easier to check position of unamplified signal in near and far field. Overlapping of signal with pump in far field should be optimized by adjusting mirror M8 (closer to input fine adjustment screws in three-part holder M8-M11). One can adjust M7 for overlapping of pump and signal in the near field. Optimize delay after overlapping of beams. Pulse energy is one of the main parameters for optimization. Some times more homogeneous spectrum is generated with slightly misaligned power amplifier delay. One can use pulse duration, shape of spectrum for final optimization of the delay. Often one has to make compromise between highest energy, clean spectrum and pulse profile when optimizing Delay 2. Signal and idler pulse duration is usually shorter than pump pulse duration, if pump is >100 fs and pump pulses are close to bandwidth limited.

g) Final optimization of the pump and the signal directions could be performed looking on overlapping in far field of all possible VIS colors (SHS, 4HI, SFS, SFI and pump) in far field. (Difference frequency generation is very sensitive to correct overlapping of signal and idler in the DF crystal. One can adjust M8 for optimization of DF.)

h) Final overlapping of pump and signal could be set by adjusting M7 for max energy at TOPAS output.

i) Final pass amplification in the same phase-matching plane as first four passes is very important. Adjust the second set of screws (horizontal tilt) in M8-M11 holder for that.

j) Adjustment of M7, M8 or M11 would require optimization of Delay 2.

k) Spectra of seed signal (SHS) and amplified signal (SHS) must match also. Different center wavelength of amplified signal corresponds to misaligned phase matching in the final pass.

Notice that usually one can find few points with week amplification besides the two strong ones while adjusting delay 2. Two positions of the delay2 (separated by ~ a full turn of the delay2 knob) give the highest output power. The first point comes then the signal is overlapped in time with the pump and the second - when the idler is overlapped with the pump (signal and idler pulses are separated in time in TD). The first one usually gives a higher output energy and stability.

- wavelength separator acron

- Except Grating we can manually acess Motors

- In Mixer I → offsets (correction: MIR 10 step, IR 3 step)
  II

  OPG offsets usually Amplifier only.

- LPT port

Dec	Hex
888 →	378
890 →	

- 100V 2f → 4 in W X 0.3

  Small

IV. Recalibration of the TOPAS

At this stage of the procedure, we want to achieve the following:

1. **Tell the computer what are the positions of the motors**
2. **Verify and optimize the offsets of the different motors as regard to the new optic position inside the TOPAS.**
3. **Set a table of the different WL, spectrum shape and the associate power.**

Repositioning the motors

So far, we manually (or using "direct access" window of Wintopas, the TOPAS operation software) changed the position of every motor during the alignment procedure. Therefore, the computer "doesn't know" anymore the position of some motors (in terms of angle or motor steps). Remember that at this stage, one should have maximized the TOPAS output by adjusting manually (or using "direct access" menu) the crystal, grating, delays, and mixers.

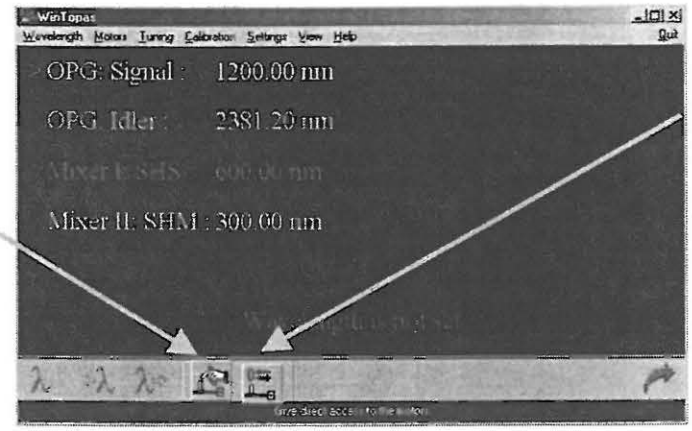


Fig.14: Main window of the TOPAS control software (WinTopas©). For a complete description of the WinTopas software, go to the user manual.

a) Since we do not want to loose lasing of the TOPAS, we cannot reset all the motors at once (we would reset too many parameters at once). So, we will rather proceed one by one (even if some motors have not been touched by hand, this is a good point to double-check the motor positions). Check the energy and the spectrum before resetting the motors.

   i. Remember the approximate position of M10 (mark it). Reset Amplifier Delay 2 motor using the reset menu *(motors/reset motors)* of the TOPAS software (see fig.16). One can mark knob of Delay 2 stage and count turns towards zero position and back.

   ii. Using the Direct Access menu *(Motors/Direct access, ref. fig.17)* at the bottom of the main window (ref. fig.14), adjust (using the arrow bar) the Amplifier Delay 2 motor until the maximum power at the output of TOPAS is regained. Then, the computer knows the position of the Delay 2 motor.

- 1hr warmup
- reinstall.
- Check out at 1.4μm for fluence overlap

- injection → horizontal → adjust 1, 2, 3 by horizontal knob
  - Vertical .. turn slit of Beam Lateral Acuity
- Timing should be the same in CPA
- N2 Superfluorescence → CPA problem
  - ↳ or BBO angle → reset

- Mixer I
  - Crystal #
    - 5 → ~1200
    - 6 → ~240°
- Mixer I
  - 8 → ~120° → AgGaSe2
  - 9 → ~240° → GaSe
- 2(SHG) 120° → SH I
- 3(SFG) 240°

- Wavelength Separator → Lightron.

Notice that the use of a power meter is recommended in order to optimize the power at the TOPAS output.

iii. Repeat the same process ((i) and (ii)) for the motor of the crystal and the grating.

iv. Simply reset the motor the mixer I (and then the mixer II when the WL desired requires its use). Do not go to (ii) for these motors since the alignment did not affect those motors.

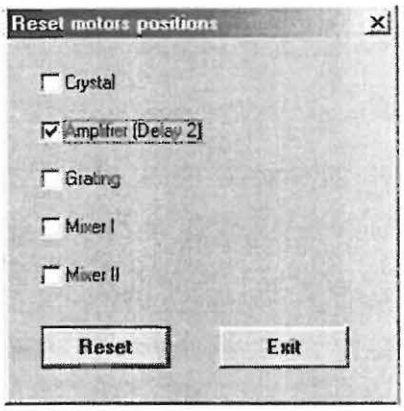


Fig.15: Reset motor menu. Here, each motor can be reset individually by checking the appropriate box.

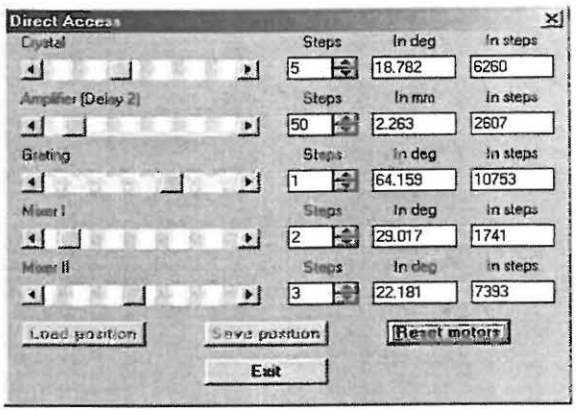


Fig.16: Direct Access to the motor menu. Here, each motor can be set manually.

Optimization of the offsets

Now, we want to find out if there is a difference between the previous calibration and the one that will match the current optics setting of the TOPAS. Such difference is express in terms of offsets for the different motors. So, in a first time, one will calibrate the OPG motors (*O*ptical *P*arametric *G*enerator elements: crystal, grating and amplifier delay 2) by using only ONE WL for the purpose of the calibration. Then, we will calibrate the mixer motor separately using a different WL for each tuning file (refer to user manual for more explanation about tuning files). One will need a spectrometer (exact wavelength calibration of the spectrometer is important) and a power meter to accomplish the OPG calibration.

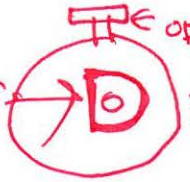
OPG

Notice here that we choose a WL of 1300 nm, same as used for the final alignment. If one used another wavelength, keep with it.

Note

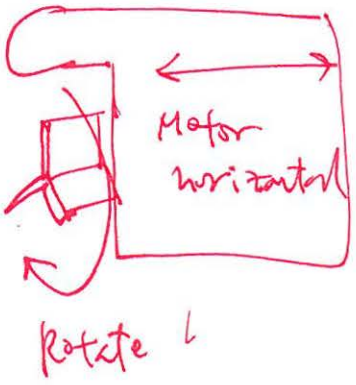
1 • USB2000 is not precise at UV & IR
(<400) (>900)

2 • (GaSe ~ Brown
$AgGaS_2$ ~ transparent

3 • 

delay crystal ← attatched for DFG crystal

4 • For DFG



120° → $AgGaS_2$
240° → GaSe

4) refer to table

filter

- Block short wavelength range

Mid-IR filter (ZnSe + coating)
Reducer : altechna@altechna.lt
www.altechna.com

CWD - ZnSe (3 mm)
Angle of incidence ~45°
Side 1 HR (1.28 - 1.5) s-pol +
HR (1.91 - 2.18), p-pol +
HT (3 - 400), p-pol
Side 2 AR (3 - 20), p-pol

- Block longer wavelength range Ge

a) Opening the Direct Access menu, take note of the current motor positions (in deg or mm, not steps). These will be used to calculate later the offsets so as to base the new calibration on the last one.

b) Block the fifth pass pump and arrange the spectrometer to measure the signal wavelength after the fourth pass (one can measure SH of signal).

c) Assuming that the TOPAS setting are close to optimum (the grating should be at least in good order), adjust the crystal angle and the grating angle alternately using the 'direct access' window to get exactly 1300 nm wavelength (650nm if using SHS) and max spectral intensity at that wavelength.

Notice that the SHG crystal position may influence the wavelength. Make sure that the Mixer 1 is also optimized for 650 nm.

d) As regard to the grating angle, use the appendix table (ref. user manual) to get an idea of the angle of the grating for a signal @ 1300 nm (or equivalently, @ SHG 650 nm).

Notice that the grating can diffract a particular WL at different angle. This is called diffraction orders. Note that the TOPAS grating operate below an angle of 70° and that the angular motor range is about 40°. Therefore, during the alignment procedure (Part III), one should choose approximately the right order of diffraction in order to be able to fine adjust the grating using the motor in this section.

Max angle is usually 30° for fs pulses. So, grating is working in the second order in all tuning range.

IF YOU ARE NOT SURE ABOUT THE GRATING ORDER (PS OPERATION): One way to set the grating angle is to start by placing the grating at 90° of incidence, and then, turn the grating towards smaller angles until it reaches the highest order (that allow lasing). This can be continued to reach even lower orders…

Notice also that the higher diffraction order used to set the grating angle, the narrower will be the spectrum (as long as the angle is ≤ 70°). Higher order of DF would ensure spectrum closer to bandwidth (BW) limit. However, if one wants to get a little higher energy per pulse, the diffraction order should be lowered. For a diffraction angle one can refer to a table in the User's Manual or use a formula:

$$\alpha = \sin^{-1}\left(\frac{m \cdot \lambda \cdot d}{2}\right)$$

with d = 300 lines/mm, is the grating parameter, m- diffraction order.

E.g. *For a <u>signal at 1300 nm</u>, the following angles are possible corresponding to the different diffraction orders (ref. table p.47, user manual):*

Signal diffraction order:	1	2	3	4	5
1300	*11.24*	*22.95*	*35.80*	*51.26*	*77.16*

For the <u>idler WL</u> = 2065.86 nm (pump=798nm), different angle can be found using the previous equation.

E.g. For Idler = 2065,86 nm, α = 18.05°, 38.30° and 68.38° for the diffraction order 1, 2 and 3 respectively.

So the highest order one reaches when going down from 90 deg corresponds to 77.16 deg. Notice that one always wants to catch the signal order, not the idler. Lets say we want to get the 4th order for the signal. Then we need to miss two bursts in topas

DFG ~20μm

GaSe

- Needtouched → 2.6μm → (0.3mW)

file DF2774.crv

20μm → (1.5 – 0.7) mW

- liquid crystal thermo-paper e.g. Edmund Scientific

OPA Power supply는 했다.

- CdTe lens & windows?
  1ea 1-7"

- Ge

a) Opening the Direct Access menu, take note of the current motor positions (in deg or mm, not steps). These will be used to calculate later the offsets so as to base the new calibration on the last one.

b) Block the fifth pass pump and arrange the spectrometer to measure the signal wavelength after the fourth pass (one can measure SH of signal).

c) Assuming that the TOPAS setting are close to optimum (the grating should be at least in good order), adjust the crystal angle and the grating angle alternately using the 'direct access' window to get exactly 1300 nm wavelength (650nm if using SHS) and max spectral intensity at that wavelength.

Notice that the SHG crystal position may influence the wavelength. Make sure that the Mixer 1 is also optimized for 650 nm.

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Notice that the grating can diffract a particular WL at different angle. This is called diffraction orders. Note that the TOPAS grating operate below an angle of 70° and that the angular motor range is about 40°. Therefore, during the alignment procedure (Part III), one should choose approximately the right order of diffraction in order to be able to fine adjust the grating using the motor in this section.

Max angle is usually 30° for fs pulses. So, grating is working in the second order in all tuning range.

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$$\alpha = \sin^{-1}\left(\frac{m \cdot \lambda \cdot d}{2}\right)$$

with d = 300 lines/mm, is the grating parameter, m- diffraction order.

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Signal diffraction order:	1	2	3	4	5
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E.g. For Idler = 2065,86 nm, α = 18.05°, 38.30° and 68.38° for the diffraction order 1, 2 and 3 respectively.

So the highest order one reaches when going down from 90 deg corresponds to 77.16 deg. Notice that one always wants to catch the signal order, not the idler. Lets say we want to get the 4th order for the signal. Then we need to miss two bursts in topas

DFG ~20μm

GaSe

- Needle check → 26μm → 0.3mW

file VF2774.crv

20μm → (1.5 − 0.7) mW

- liquid crystal

thermo-paper e.g. Edmund Scientific

EPA Power supply 安定.

- CdTe laser window?
  - 1μ
  - 1.4μ
- Ge

output power (one at 77.16, second at 68.38) and stop at the third when turning the grating from ~90 deg.

Wintopas software will rotate angle of grating according to WL of signal.

e) Once the optimum grating angle is set (part c), go to calibration menu (ref. fig.17) (*Calibration/correction*) and then, enter the new grating position value in deg calculated (or taken from the table) according to the measured wavelength, so that the software can calculate the difference between the current calibration and the previous one and set a new affix relative to the real zero angle of DG and zero position of rotation stage.

Notice that only the real value (position) has to be entered. The affix is automatically calculated once the correction updated.

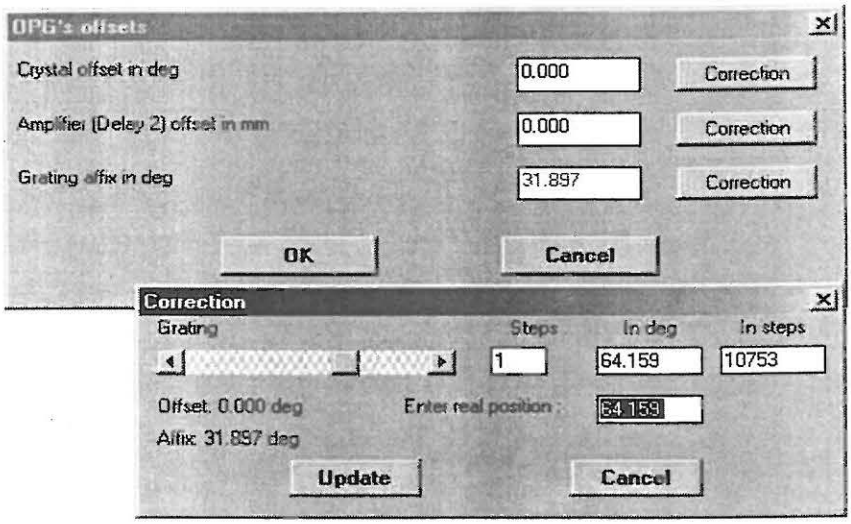


Fig.17: Calibration menu that allows one to enter offset corrections for the grating (OPG in general).

f) Remember the crystal position in deg from 'direct access window". Set the WL at 1300nm (650 nm) *(Wavelength/Set wavelength)*. Go to calibration menu, in the crystal offset correction menu, and then, using the arrows, get the remembered number in the deg box. Update the changes. Alternatively one can calculate the offset subtracting the old crystal motor position from the new and enter the value into 'crystal offset in deg' box (OPG offsets). Then, enter the real value of the delay 2 position and then update the value to calculate the offset of the delay 2.

Notice that one should take note the of previous position values before to update the value in case that a manual calculation is required.

At this stage, it would be important to make the following verification. Using a spectrometer, check that the fifth pass amplifies the same wavelength as generated in the fourth pass:

i. Block the fifth pass pump and measure the signal wavelength after the fourth pass (one can measure SH of signal).

ii. Open the fifth pass pump and measure TOPAS output signal wavelength. Tweak the horizontal adjustment knob of M11 to get the signal wavelength exactly the same as the fourth pass signal wavelength.

Notice that with ps-TOPAS one can use a power meter instead of a spectrometer. In picoseconds max output power closely corresponds to a good phase matching angle.

Before to proceed with the mixers calibration, one should try to set a different WL for the signal and verify that the motor positions set by the computer correspond to the optimum positions. To do so, check the effect of changing (direct access) the motors position on the output power.

Mixer I

a) Since the mixer I motor has already been reset previously, the calibration of **Mixer I** can follow the basic steps described in a), c) and e) of the previous section on OPG's. Use the Calibration menu to set the offset (ref. fig. 18).

Notice here that one will need to make the calibration (offsets) for a WL that is different for each tuning file. That means that there is a different offset value (for the mixer I) for each of the tuning file.

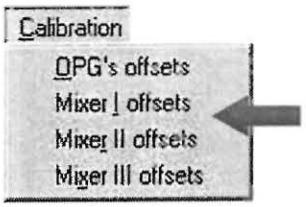


Fig.18: Calibration menu that allows one to enter offset corrections for the Mixer I and the Mixer II (Mixer III is available for Deep UV option only).

Mixer II and Mixer III

a) Similarly for the mixer II and mixer III.

Calibration table

Now that the offsets are known, we want to update the table of the WL vs Output power of TOPAS to be used as checkpoint(s) in day-by-day alignment. We refer the reader to the calibration files (corresponding to the tuning files) for an updated version. Our goal here is to provide with a value of TOPAS output power vs WL, and this, for the different WL ranges covered by the different tuning files. A spectrometer will be, once again, needed to achieve this task.

Notice that by placing the fiber end of fiber spectrometer behind a business card (for diffusion purpose), one would get enough light for the spectrophotometer and yet, will avoid saturation.

Usual problem of fiber spectrometer is modulated spectrum when higher modes are generated in fiber or input slit is too big.

a) Starting at the bottom of the WL range set the appropriate WL tuning file in the WinTopas software.

b) Then, set the first WL listed on the table using *Wavelength/set wavelength* menu. Once the TOPAS is set at this WL, verify the WL using the spectrometer and read the power on a power meter placed before the fiber end (use wavelength separators/ filters to have just that wavelength at the power meter).

c) Set the next WL on the table that is still included in the same tuning file.

d) Repeat steps a), b) and c) until the entire WL range is covered (all tuning files covered)

e) One can measure offsets of Mixers by maximizing the energy of given WL.

Fourth pass focusing adjustment

For the same reasons, if the beam parameters are changed in the pump laser, the collimation lenses in the fourth pass could be adjusted.

c) Adjust first L3 laterally on the base slot in order to get highest intensity in the crystal. Then, if L3 is not enough to focus properly, adjust in the same way the lens L3'.

Notice that if the focus is too much, one can decrease the intensity of the beam using A3 to lower the power on the crystal (to avoid burning). Remember that the beam size of the fourth pass has to be small for two reasons: first, to have intense enough to pre-amplify the seed and second, to select a limited spectrum of the diffracted light from the grating.

Spatial filtering is performed here also. Small beam focused at long distance would have clean central part and blur peripheral area in focal point. This spatial filtering helps to generate a homogeneous seed beam.

Fifth pass collimation adjustment

For the same reasons, if the beam parameters are changed in the pump laser, the collimation lenses in the fifth pass must be adjusted.

d) Adjust first L6 laterally on the base slot in order to get the beam collimated (check that the beam size does not change over distance).

Notice that final signal and idler beam size and divergence will depend mainly on shape and divergence of pump. Make diffractive divergence of pump in order to maximize the energy of mixer stages (Difference frequency is most sensitive mixer stage. Signal and idler are conjugated pulses and beams. Diverging signal would correspond to converging idler and vice versa.)

APPENDIX II: Additional procedures

In the case that one HAS TO modify the beam profile or the beam size/divergence of the pump beam entering the TOPAS, the collimation lenses have to be adjusted inside the TOPAS to compensate for the new pump beam parameters. The following procedures are related to that particular situation.

First three passes focusing adjustment

When one change the beam divergence and the beam size of the pump laser, one need to adjust L1 to make sure that there will have enough intensity on the crystal to produce and amplify superfluorescence in the first three passes.

a) The lateral adjustment of L1 (horizontal position on the base slot) will change the size of the beam on the crystal. We want to get enough intensity to get superfluorescence but yet, not to burn the crystal. Therefore, by precaution, scan SLOWLY increasing the intensity (ref. fig. A2). Make A2 smaller at this point to prevent too high intensity at some elements. Make smallest possible pump beam after three passes. Then open slowly the A2.

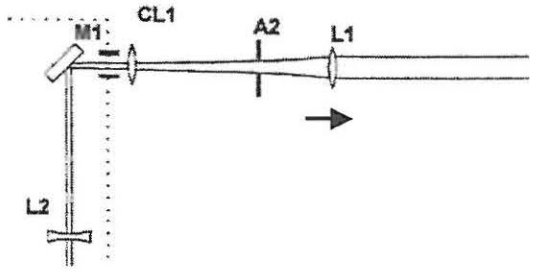


Fig.A2: Top view of adjustment direction of the lens L1 in order to change the intensity of the beam on the crystal.

b) Make sure that the vertical alignment of the first and third pass still good while scanning the L1. Also, if the beam is too wide or blurry on the card before CL2, that means that the beam is too intense on the crystal. There is two possible solutions: close A2 a little until the beam looks good, **or** move L1 more carefully and more finely to get the right position that will allow the right intensity on the crystal.

Notice that if the lens is already aligned and the beam is slightly blurry, try using the aperture. However, if a major alignment of the beam is required, try moving the lens to the appropriate position.

Change BS1 to higher reflection if pump intensity in the first three passes is too high and one has to reduce pump beam diameter (by A2) significantly.

Abbreviation significations

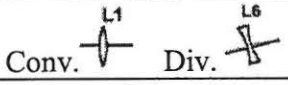
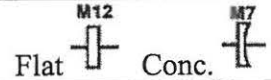
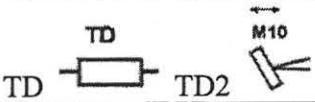
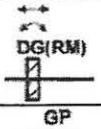
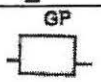
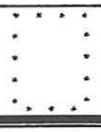
Sample abbreviation	Signification	Sample symbol
A1	Aperture	
BS1	Beam splitter	
L1	Diverging or converging lens	
CL1	Cylindrical lens	
M12	Flat or concave mirror	
CM1	Cylindrical mirror	
PR	Polarization rotator	
NC	Nonlinear crystal	
TD	Time delay	
DG	Diffraction grating	
GP	Fused silica plate	
.....	Main assembly element	

Table.A1: Significations of the abbreviations used on the TOPAS layout.

APPENDIX I: TOPAS Layout

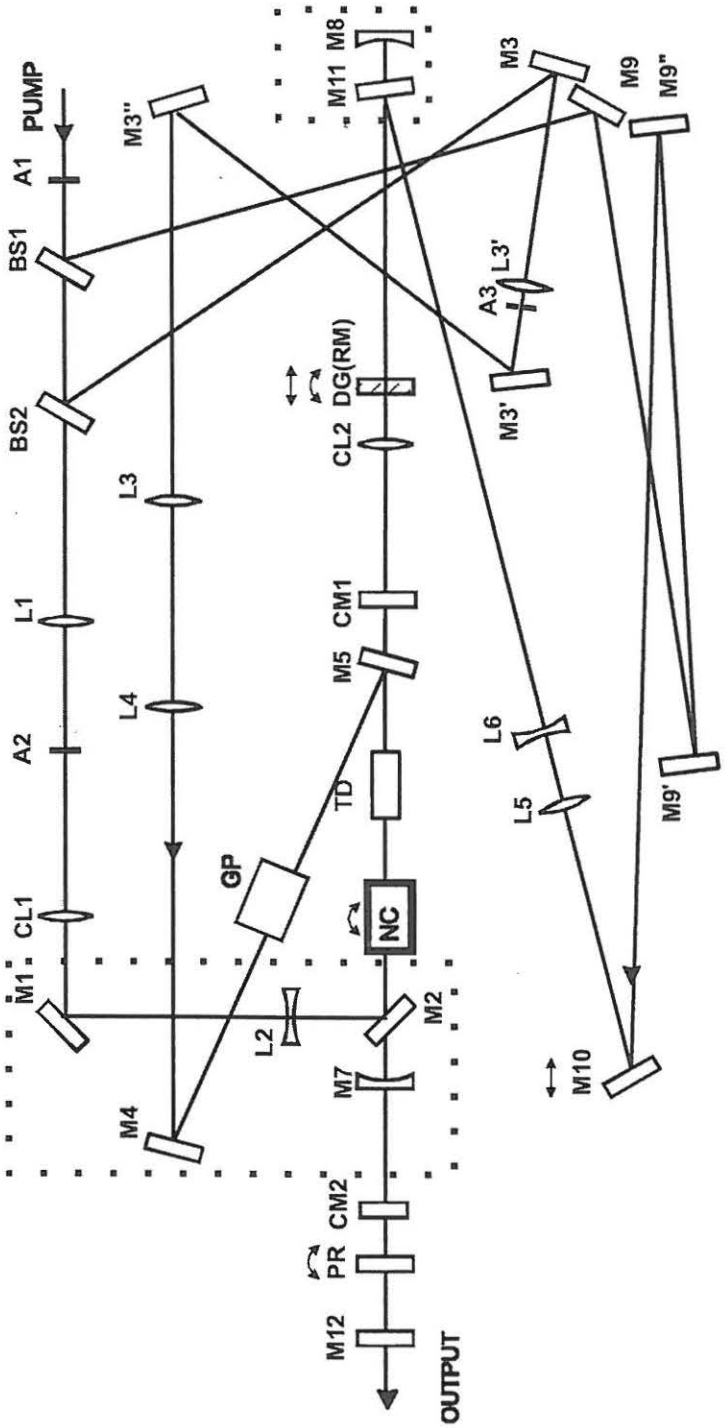


Fig. A1: Top vew of general layout of the TOPAS optical elements. The five passes are represented simultaneously and the significations of the abbreviations are given in Appendix I below.

TOPAS FINE ALIGNMENT PROCEDURE

NOTE: This list of procedures is an addition for training course only. The full alignment procedure is referred to TOPAS manual and should be performed only by well-trained and *patient* persons. For reference to optical components, the reader is referred to the TOPAS layout figure included in appendix I of this document.

PART I: Understanding the TOPAS

At this stage, we want to give a detailed feeling to the reader about what's going on at each stage of the TOPAS. An alignment procedure will follow at the next section.

First, second and third passes: seed beam

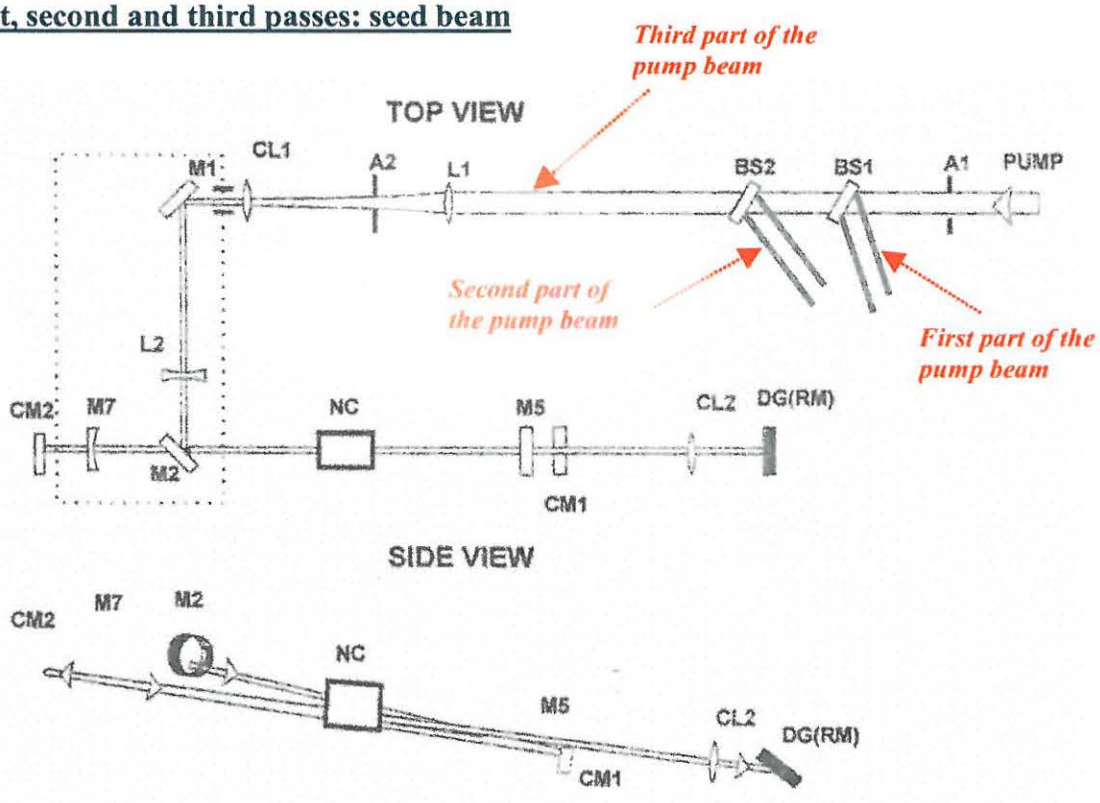


Fig. 1: Top view and side view layout of the first, second and third passes light paths inside the TOPAS.

1) The pump beam is split into three components. The first two are going to be used for the fourth and fifth passes (amplification). The third component is the light that passes through BS1 and BS2 to be reflected by the main assembly towards the NL crystal and is referred as *seed light. However, notice that in reality, this is the pump that generates parametric superfluorescence or seed light inside the TOPAS*. This later component of the light will do in total three passes in the crystal, which they will be called respectively the first, second and third passes. From the BS2 to the crystal, the beam will be collimated by the telescope optics between BS2 and the NL crystal to a spot size of around 1-2 mm.
2) The first pass goes from M2 to CM1. That first pass is pumping the crystal in order to produce parametric superluminescence (SF).
3) The second pass is the backward reflection from CM1, through the NL crystal, up to CM2. This second pass amplifies the superluminescence produced by the first pass.
4) The third pass is the reflection from CM2 to the diffraction grating. The third pass passes just above CM1 to that it can reach the DG. The third pass amplifies the second pass output. *Notice that parametric generation/amplification differs from laser amplification: one does not have any build up of any population inversion in a nonlinear crystal. Parametric amplification works through electronic nonlinearity of a medium and thus is a very fast process (<fs). So the second (the third) pass does not "feel" the previous pass pump.* One can see a different visible color (e.g. green when signal is set to ~ 1500 nm, on top of the pump at 800 nm) on a white card before the lens CL2. The overlapping of the first three passes gives enough power to generate, already at this stage, superluminescence in the crystal. At CM1, both the first and the third pass should be in the same vertical plane (remember, the second pass beam spot is visible only before CM2 or before the main assembly if one keeps a paper-card low enough not to block the first pass).
5) Notice that the third pass will pass in the slit before CL2 to ensure a proper alignment on the grating. Then, it will hit the grating. The spectrum of the beam will then be diffracted (spread) spatially (ref. fig. 2) while reflected back through M5 to the crystal. This will become the fourth pass when the second part of the pump will be applied (ref. fig. 1).

Fourth pass: pre-amplification of the seed beam.

At this point, we basically have a seed beam, relatively weak, with a spectrum that is reflected on the crystal. This seed beam will be pre-amplified by the fourth pass pump beam. Since the fourth pass pump beam is collimated to a narrower radius (≤ 2mm), only a narrow spectrum of the diffracted beam will be amplified. That's why, by changing the angle of the crystal, we can tune the WL amplified since the crystal generates different pairs of WL at different angles. ***Notice that the purpose of the grating is to narrow the spectrum (together with the 4th pass, see principle on fig. 2).***

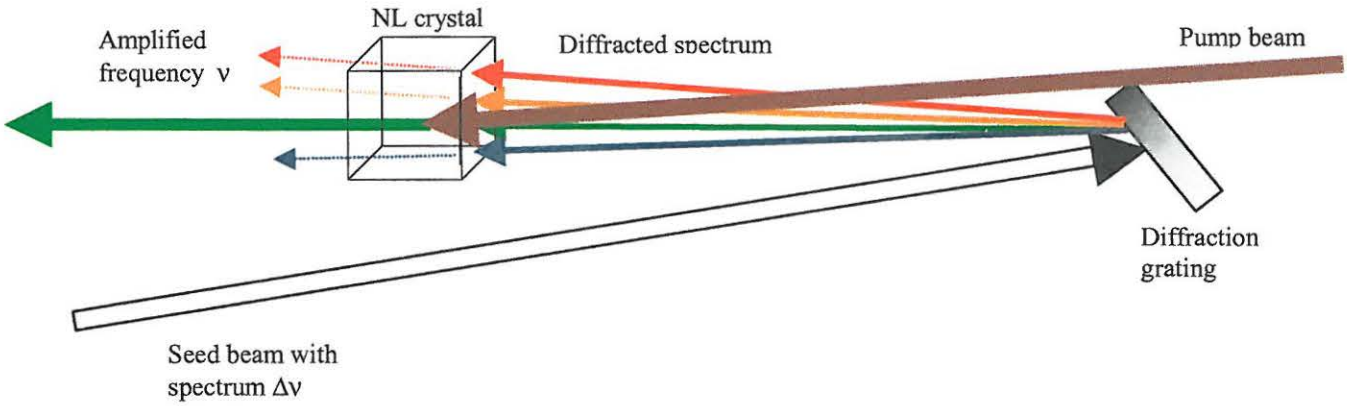


Fig. 2: Scheme showing the main principle of the pre-amplification in the fourth pass. The spectrum of the seed beam (1-2-3 passes) is spread on the crystal, reflected from the DG. Then, the fourth pass pump beam comes to overlap on the crystal, but only on a narrow area, corresponding to a much narrower bandwidth of the seed beam (amplify only "one" wavelength), depending on the phase matching condition between the seed, the pump and the crystal angle.

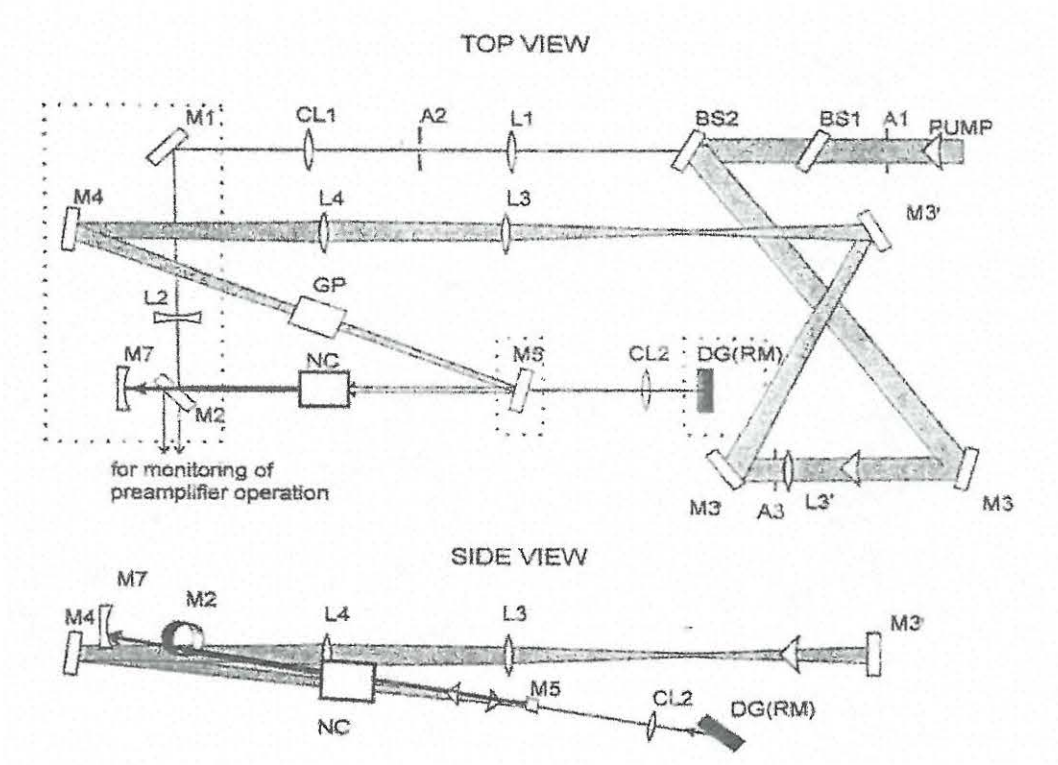


Fig. 3: Top view and side view layout of the fourth pass light path inside the TOPAS.

1) About 2.5% of the incoming (from TITAN) pump beam is used for the fourth pass. First, it is collimated and focused to a narrower beam size ~1-2 mm (by passing through L3, L4 and M4) in order to be able to select a narrower BW and to have enough intensity to amplify from the seed). This pump beam acts as pre-amplification only, since the power is low (but intense enough due to the smaller spot on the crystal). *Once the fourth pass will have selected a BW of the seed by pre-amplification of it, then will come the fifth pass, with higher power, bigger beam size, to amplify that BW to the final output power level required.*
2) The fourth pass pump beam then traverses a glass plate (GP) that compensate for the lateral drift of the first three passes introduced when crystal changes its angle (to ensure that the pump beam hits the mirror M5 always at the same spot as the seed).
3) Then, M5 reflects the pump towards the crystal. The grating is mounted on a delay stage so that one could adjust the delay between the seed pulse and the pump pulse so that they can overlap no only in space, but also in time IN the crystal. This is the DELAY 1 adjustment.
4) Then, the small beam spot hit the crystal and amplify the appropriate WL depending on the angle of the DG and of the crystal.
5) Then, the pre-amplified seed beam goes through M2 where the pump is removed (filters the pump light @ 800nm) and the seed is reflected by M7 (focusing mirror). Due to the mirror M2, the pump is reflected on the side, towards M10. One could see the reflected spots of the second harmonic of the pump on a card placed on the side of M10. Then, the cleaned seed beam goes back ABOVE the crystal, and ABOVE M5 to hit M8.

Fifth pass: final amplification.

At this point, we have a seed beam that has been pre-amplified by the fourth pass and that the spectrum has been narrowed by use of the diffraction grating spreading in combination with the spot size of the pump beam in the fourth pass. Now, we want to take this seed and amplify it to its final power level by using most (95%) of the incoming pump beam from TITAN. To do that, we will need to overlap in space and in time the fifth pass with the seed beam IN the crystal. This will involve a delay 2 adjustment.

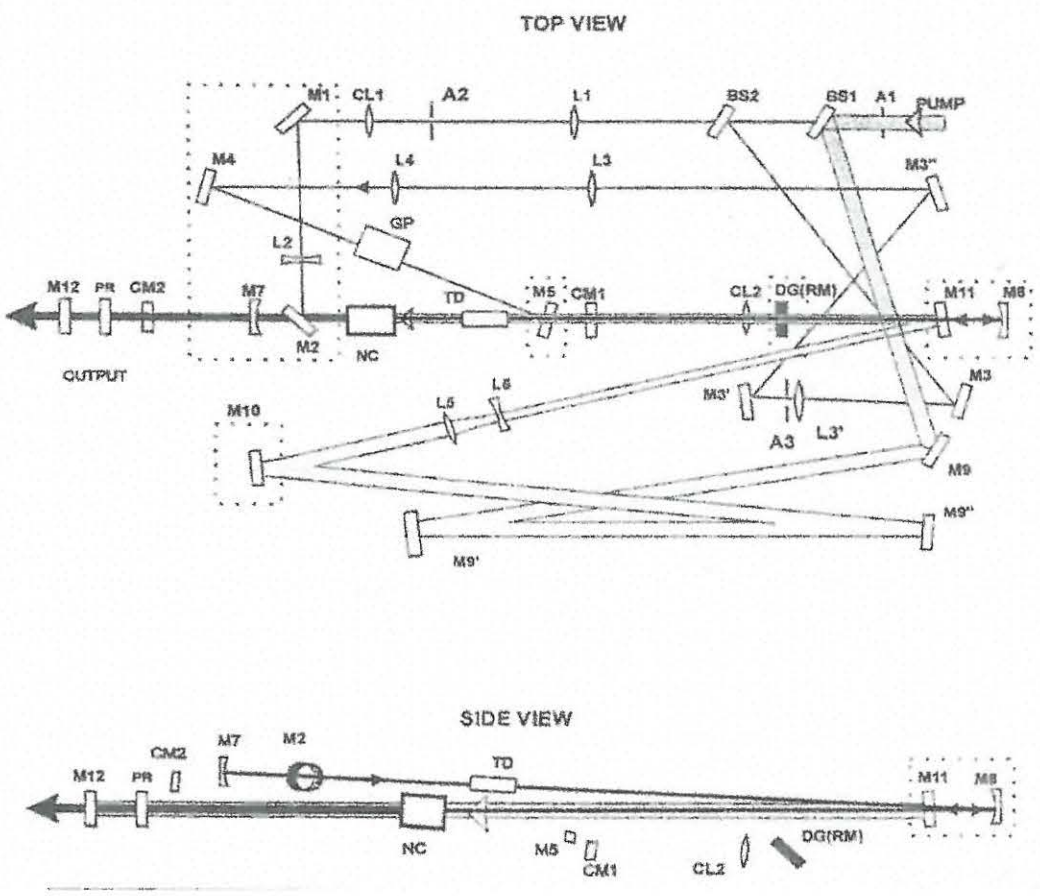


Fig. 4: Top view and side view layout of the fifth pass light path inside the TOPAS.

1) About 95% of the incoming pump from TITAN is used in the fifth pass. The beam is collimated to a beam spot size that will approximately cover the surface of the crystal. This is in order to maximize the amplification in the crystal, but yet, not to overpump (beam gets distorted) the crystal by having a reasonable intensity in the NL crystal.

   Notice here that before L5 and L6 that act as telescope objective (collimate the beam), the pump beam pass by the mirror M10 mounted on a delay stage. Again, as in the fourth pass, this delay (co-called DELAY 2) will be use to overlap in time the seed beam from the four first passes with the pump beam of the fifth pass.

   Notice also that from M11 to the output, the fifth pump beam path should be collinear with the fourth pass seed path.

2) Then, both the pump and the seed pass go through the crystal. Because of the high intensity, parametric amplification occurs (see Saleh & Teich, chapter 19, p. 748-750 for more info), according to the angle of the crystal and DG.

3) Then, the pump beam is blocked at the output (by M12) and the signal and idler come out. The mixer I and/or II can be combine to produce SHG of both idler and signal.

PART II: Aligning the TOPAS

This procedure contains two major steps. The first step is a verification procedure. No optical elements should be touched. This is only a diagnostic procedure. Some external mirrors may be tweaked, but NOTHING INSIDE THE TOPAS SHOULD BE TOUCHED.

Diagnostic: TITAN pump beam

1) Check the pump laser performance and the TOPAS pump beam parameters such as energy, pulse duration, beam quality to correspond the specified values. The TITAN power should be approx. 1,80 W, pulse at 1 Khz, ~ 2 – 2,5 ps duration, beam profile aspect ratio of 1,5/1 MAX. If possible, check the contrast ratio of the TITAN pulse, using a fast photodiode. The contrast ratio should be around 1/100 (or 100, depending on convention).

Diagnostic: TOPAS optical elements

2) If the pump is OK, check the TOPAS optical elements (especially the main BBO crystal) for possible damage.

Diagnostic: TOPAS alignment

3) If everything is OK, check the TOPAS alignment:

   a) Reset all TOPAS motors. Set the signal WL to 1500 nm.

   b) (ALL PUMP PASSES BLOCKED) Check that the input beam is centered on the input aperture A1.

   c) Check that the beams in the first three passes and the fourth pass are in one vertical plane. To do so, check the third and first passes by placing a card before CM1. By scanning in height of the card, one could see the first and third pass alternatively and verify their alignment. (FOURTH PUMP PASS UNBLOCKED) The fourth and the first passes could be checked by placing a card before the NL crystal (between NC and M5).

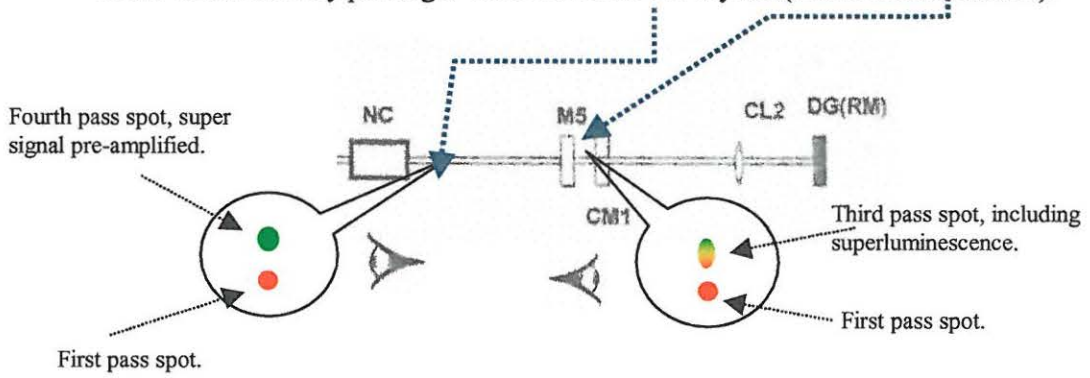


Fig. 5: Views of the beam spot configuration on the card when checking for the first, second, third and fourth passes.

d) (PUMPS BLOCKED) Check that the third pass beam goes right through the horizontal slit of CL2 holder.

e) (PUMPS BLOCKED) Check that you get parametric super signal after the third pass (one should see some visible light on top of the 800 nm light). Look on a white card before CL2.

f) (5TH PASS PUMP BLOCKED) Check that you get amplification in the fourth pass (one should see two bright visible blue AND green spots going away from the main assembly towards M10). Likewise, one could see an intense visible beam (from signal&idler superluminescence with the pump) when placed a card before M5 (beam coming from above NL crystal).

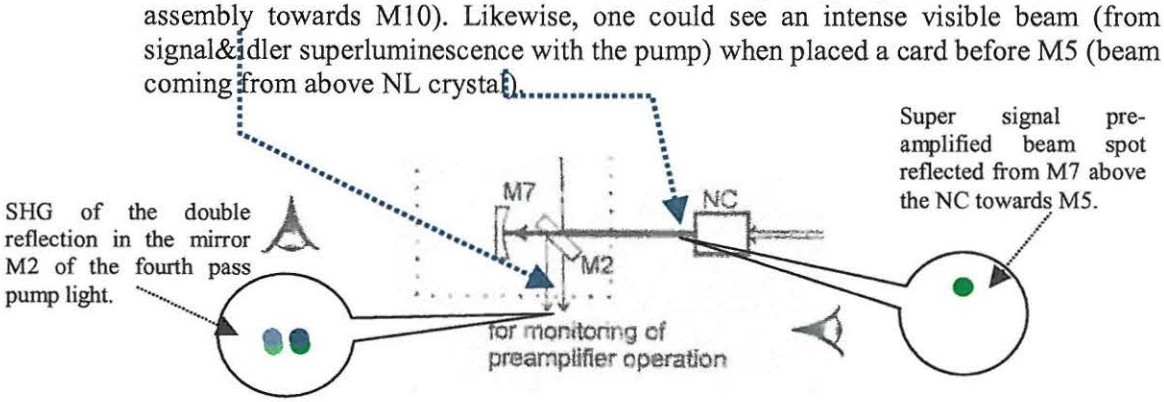


Fig. 6: Views of the beam spot configurations on the card when checking for the pre-amplification at the fourth pass.

g) (ALL PUMPS UNBLOCKED) Check that the pump beam and the seed beam are collinear in the fifth pass. To do so, one could first check if the fifth pass pump overlap with the seed on M8 (place a card between M11 and M8, block and unblock alternatively the 5th pump and see if the spots on the card overlap in space. Use goggle at 800 nm to see the SHG of the pump, which is weaker and easier to see). Second, one could check the same overlapping, but this time, at the output of the TOPAS (same procedure, but make sure the pump blocker -mirror- is removed). Set signal WL to 1300 nm and use SH generator to visualize the signal at the TOPAS output.

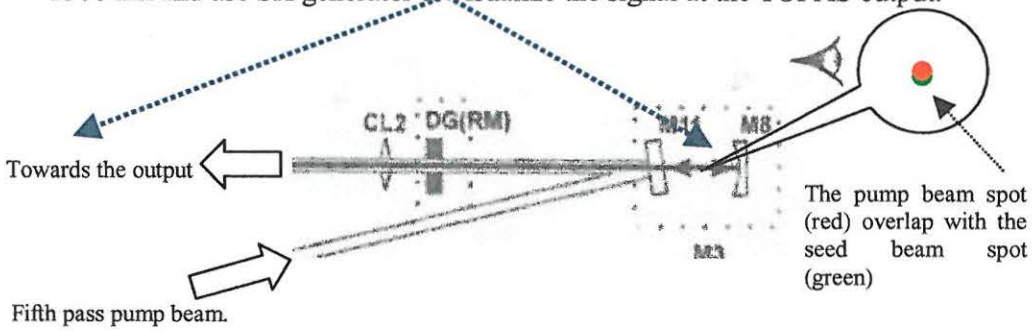


Fig. 7: Views of the beam spot configurations on the card when checking for the fifth pass overlapping with the seed.

Try to restore the alignment by tweaking **just the external beam rooting mirrors**. If that is not possible, refer to the next section that describes more detailed realignment procedure of the TOPAS.

THE SECOND MAJOR STEP IS THE REALIGNMENT PROCEDURE ITSELF. IN THAT CASE, OPTICS INSIDE WILL NEED TO BE ADJUSTED AND THEREFORE, A RECALIBRATION OF THE TOPAS WILL BE NECESSARY TO BE PERFORMED. THIS PROCEDURE IS FOR WELL TRAINED PERSONS ONLY AND SHOULD REQUIRE A LOT OF ATTENTION AND UNDERSTANDING.

Realignment: First, Second and Third passes: seed signal

Align the first three passes using the external mirrors:

a) Check that the input beam is centered on the input aperture (A1).

Notice that if one touches the input mirror, the aperture A1 and A2 should be set so that, once the first three passes aligned, the beam passes in the middle (center the apertures) of A1 and A2.

b) Check that all three passes are in the same vertical plane. It is convenient to check the beam positions on CM1 mirror: the beam after the third pass (that goes just above the mirror) should be right above the first pass beam (that strikes the top edge of CM1). See fig.5.

Notice that if one wants to align the TOPAS at a different signal WL, by turning manually the crystal (using the appropriate knob, see fig. 11), it is possible to change the color of the superluminescence seed (e.g. for signal at 1500 nm ~ green, at 1600 nm ~ yellow, at 1300 nm ~ purple).

c) Check that the second pass hits the mirror CM2 (use paper card). If one cannot hit CM2 using the external mirror, try to adjust the tilt of the CM1 using an Allen key.

d) Check that the third pass beam goes right through the horizontal slit of CL2 holder. Check if the second pass hits the mirror CM2 (see a beam spot on card placed before CM2). If the third pass is too high or too low, one could try, first to align the external mirror to get the first three passes aligned, with superluminescence, but if even once aligned, the third pass does not go through the slit, one could then adjust the tilt of CM2 using Allen key.

Notice that the beam at the third pass should be vertically stretched since it passed through cylindrical mirror (CM1 and CM2) and cylindrical lens CL1.

e) Check that when the aperture A2 is closed (or smaller diameter), the visible superluminescence signal goes away. This is due to the fact that by closing the A2, the power in the crystal drops and the power is no longer high enough to produce superluminescence.

f) If you cannot get any visible light after the third pass, it may be the indication that the pump laser is not working properly. Proceed further only after making sure that the pump is OK and that the first TOPAS passes have no damaged optics including the crystal. Also check that the crystal position is OK. Reset the crystal if not sure.

g) If everything is OK and still no visible light can be detected after the third pass, try to move the lens L1 to get a higher intensity in the crystal and some visible light after the third pass. Mark the beam position in front of CL2 before releasing L1, and try to maintain the same position when moving. Go through this section once more to check the first-third passes after securing the L1.

FOR MORE DETAILED INFORMATION REFER TO THE TOPAS USER'S MANUAL SECTION 3.4 FIRST, SECOND AND THIRD PASS ALIGNMENT.

Realignment: Fourth pass: pre-amplification of the seed.

At this point, the first three passes should be aligned. So, the external routing mirror should not be touched anymore, unless it is for very fine optimization later on. Remember that the third pass should already have superluminescence signal generated only with the power contained in the first three passes. Now, we have to make sure that the seed reflected from the grating collinearly overlaps spatially with the pump in the fourth pass and adjust the time overlap between the pump and seed pulses if needed. Then, with the fourth pass, we will pre-amplify a part of the spectrum of this seed signal using a part of the incoming pump (2.5%) from TITAN. Refer to the part I for more general explanations.

Here, for convenience purpose, the procedure assumes that the TOPAS is set to a signal close to 1500 nm (reset motors if any has been touched by hand). So, the superluminescence signal should be green (to be more exact, superluminescence signal is in IR, however it produces some green when mixed with the pump in the same nonlinear crystal).

a) First, make sure that the pump beam is not clipped anywhere from BS2 up to the crystal. Make sure that the beam is centered on the aperture A3. If it is clipped, one can adjust the tilt of the BS2 by adjusting the top Allen screw and by tilting slightly the beamsplitter.

b) Observe two spots going away from the main assembly towards M10 (side reflection of M2). Since both the pre-amplified seed and the pump are passing through M2, the spots should be composed of SH of the pump (blue spots at ~400 nm) and some seed green light (when at 1500 nm) (see fig. 6 If you see no green even with A3 fully opened, that means that there is no amplification. If you have amplification, go to Realignment: Fifth pass: final-amplification of the seed. Likewise, one could see an intense visible beam (from signal&idler SF with the pump) when placed a card before M5 (beam coming from above NL crystal)

c) One way to align the fourth pass, is to use the 0 order diffraction from the DG. That means that instead of reflecting seed at the second or third order with a particular angle, the seed is reflected at approx. 0 deg.

   i) First, block the fourth and fifth pass pump beam before M3 and M9. Then mark the grating holder (moving part) position with respect to its sleeve (still part). Then, unscrew the screw ① (using Allen key) on the side of the grating (ref. fig.8) and tilt manually the grating to approx normal incidence to the third pass.

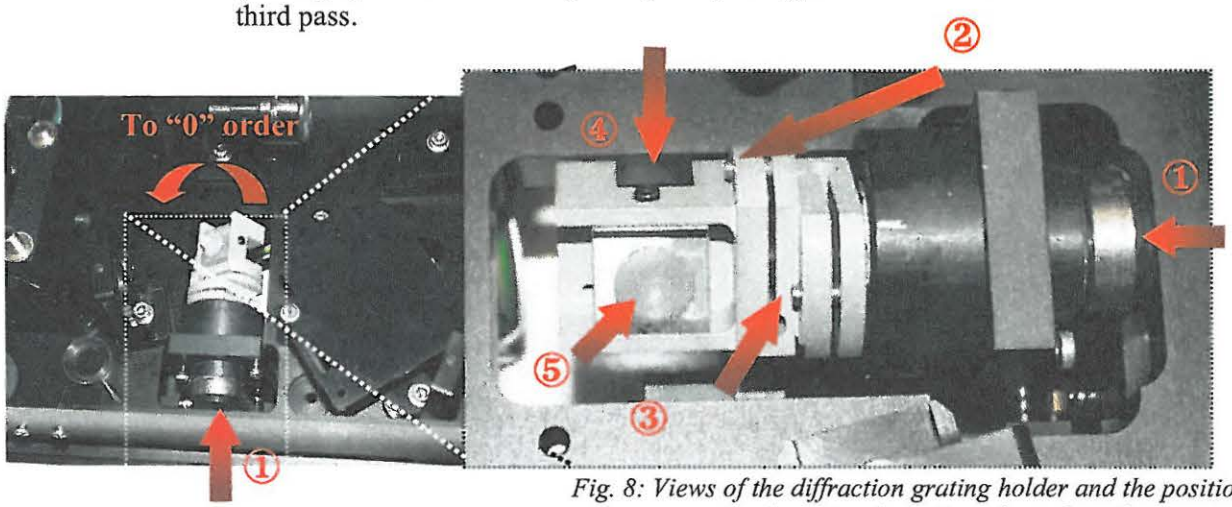


Fig. 8: Views of the diffraction grating holder and the position of the screw we have to release in order to be able to set manually the 0 order of the DG. Notice that on this picture, the grating angle is NOT at the 0 order position, but the direction of the rotation is shown.

ii) Then, fine adjust the grating angle using the knob (see fig. 11) to get green light reflected above CM1 on a card placed just above the third pass spot.

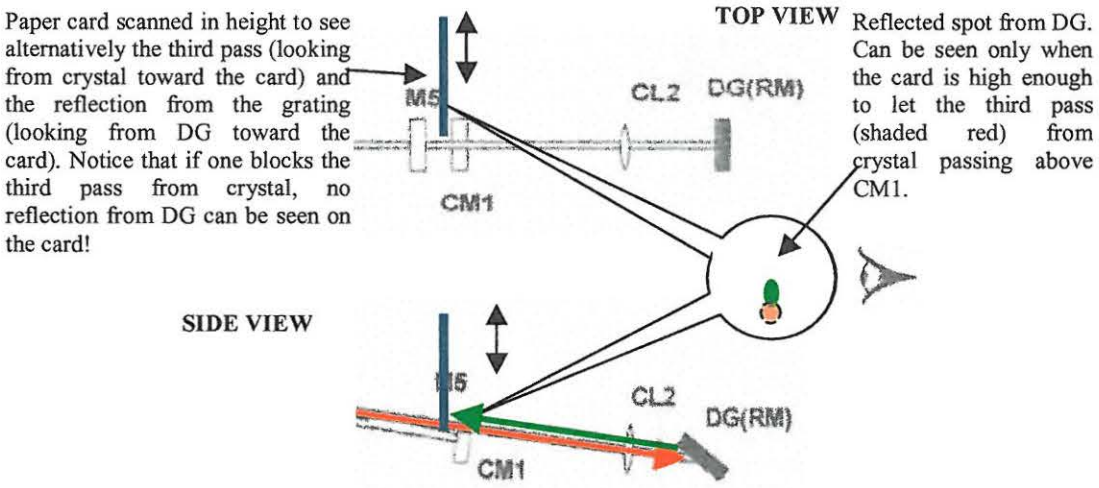


Fig. 9 Views of the beam spot configurations on the card when checking for the reflected third pass from the DG in order to align the fourth pass.

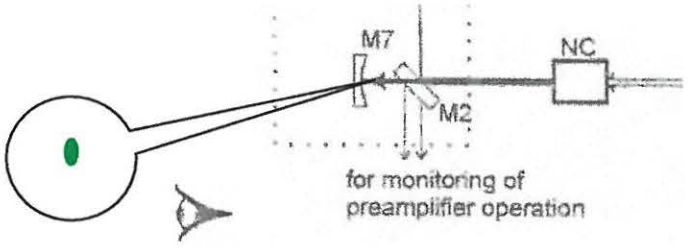
Notice that by touching the grating screw ① (ref. fig. 8), one will loose the calibration of the grating. Therefore, a calibration will have to be performed after alignment.

ii) Then, make sure the reflected seed from the grating is in the same vertical plane than the third pass. One can adjust the horizontal alignment by adjusting ③ (ref. fig.8).

Notice that the reflected beam from grating passes through the mirror M5 where the pump at 800 nm is blocked and only the green light is going through the crystal.

iii) Then, make sure that the reflected seed beam pass above CM1 (step ii), in the crystal (on the top part) and hits the mirror M7 (see fig. 10). If one cannot see the beam on M7 (when pump is blocked), a vertical alignment of the reflected beam at the grating is possible using the grating angle knob (ref. fig.11). Also, one can see the seed beam in front of the main assembly just above the first pass. Make sure the seed passes through nonlinear crystal, not above.

Fig.10: View of the beam spot configuration on the card when checking for the reflected 0 order third pass from the DG on M7 (4TH AND 5TH PUMPS BLOCKED).



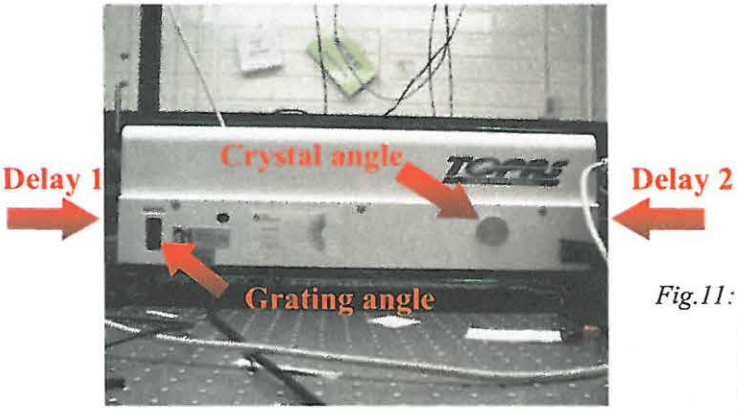


Fig.11: Side view of the TOPAS box. There is a knob controlling the angle of the crystal and also a knob controlling the angle of the grating.

iv) Also, check that the fourth pass pump beam passes through the glass plate GP, hits M5 and is reflected on the crystal, in the same vertical plane than the 4th pass seed.

v) Now that the seed beam goes up to M7, let's spatially overlap the pump beam with the seed. Place a paper card before the crystal, and check that the pump beam is in the same vertical plane than the green seed and the second pass beam spots. Ultimately, we want to overlap the pump beam (blue spot on the card using goggle @ 800nm, since blue ~ SHG of 800 nm) with the green seed beam. Move M4 to adjust the height of the pump beam, and move M5 to adjust the tilt (horizontal displacement). Verify that the overlapping occurs before and after the crystal (ref. fig. 12).

To verify the overlapping, block alternatively (ON/OFF) the pump beam before M3 to seed green and then the blue overlapping the green spot.

The overlapping of the pump (intense) and the seed is easier using the goggle @ 800 nm that allows to see the SHG (blue spot less intense) as well as the seed beam at ~ 532 nm.

A verification point is before M2, where, when the card is place high enough, will see the vertical alignment of the seed and the pump. When the card is lower, one will see the first pass beam (have to scan the card in height to see second pass, and therefore, disabling the fourth pass).

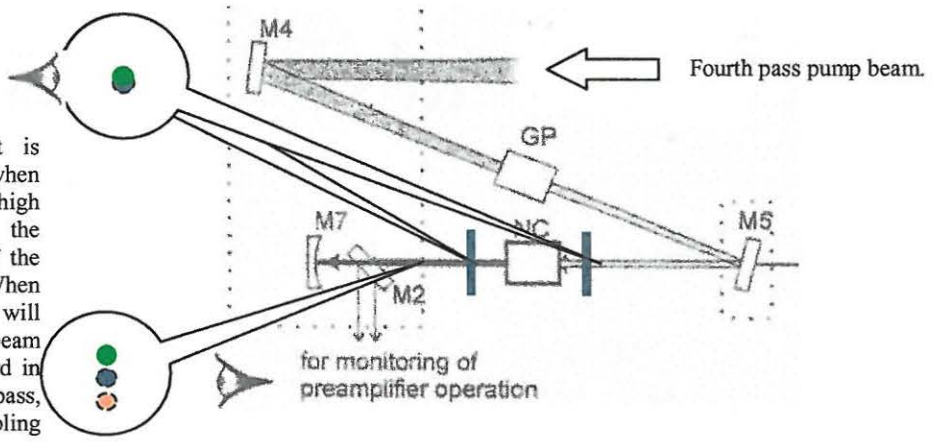


Fig.12: Views of the beam spot configuration on the card when checking for the overlapping of the fourth pass pump beam and the seed beam before and after the crystal. Also, a view of pump and seed alignment in the same vertical plane.

Notice that by overlapping the pump and the seed immediately before and after the crystal will approximately overlap the two beams WITHIN the crystal. Then, we will optimize the overlapping by fine adjustment later.

d) Now that we have an approximately good spatial overlapping, place a card in front of the M5 so that one could see the fourth pass reflected from M7 and coming from above the crystal. Then, adjust the delay 1 knob (ref. fig. 11) so that the intensity of the seed green spot on the card is maximized. The delay 1 will overlap in time the pulses of the pump with the pulses of the seed.

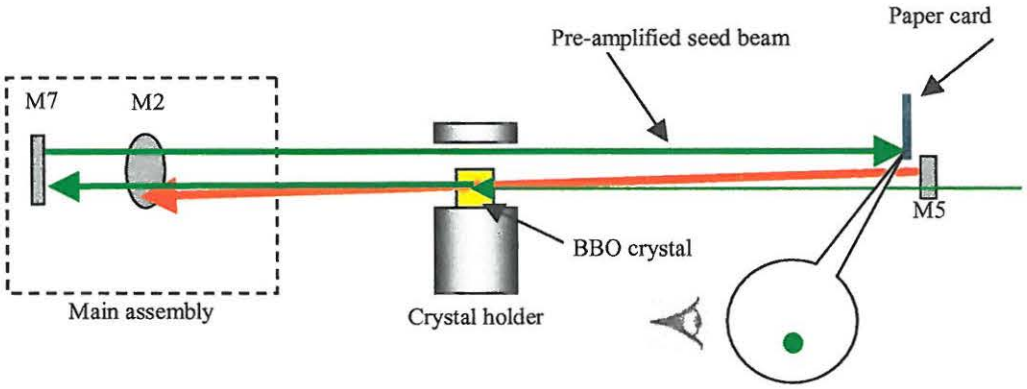


Fig.13: Side view of the fourth pass trajectories for the pump and the seed. The pre-amplified seed beam is viewed on a card place between the crystal and M5, and is used to maximize the overlapping.

Notice that the blue-green spots on the side of the main assembly (side of M10, on the card) should therefore be maximized once the time and spatial overlapping is adjusted.

Notice that the pump intensity in the fourth pass must be below the threshold of superfluorescence when the seed is blocked. The superfluorescence may be easily detected just after NL crystal. Superfluorescence will have much bigger beam diameter of VIS (yellow-green-reddish) light than the amplified beam. Generation of supercontinuum (colored concentric rings) indicates that the pump intensity is much too high. Close A3 to reduce the intensity.

e) Now when we have the 4th pass working with the grating in the 0 order, the following step is to get the grating back to the working order. Reset the grating motor. Unscrew the screw ① and tilt the grating face down and match the marks that should have been made before releasing the screw for the first time [this will ensure that one catches at least the same order as that before the readjustment]. If you don't have any marks, follow the grating calibration procedure in the TOPAS manual.

Realignment: Fifth pass: final-amplification of the seed.

Now that the four first passes are aligned, we will need to get a visible output to maximize the overlapping in the fourth pass and to align the fifth pass. Therefore, we need to set the TOPAS to a signal WL that will produce a visible light once at the output of the mixer 1.

a) Set the TOPAS to 1300 nm*. Block the fifth pump before M9, insert a business card in front of M11 and observe the visible spot that comes from M7. If you can see three visible spots (yellow, blue, red) in a row, the beams are slightly not collinear in the fourth pass. Tweak M5 to overlap all the spots.

* If the grating has been set to the 0 order and back using the screw ① (see fig. 8), its position may not be exact, so tune the grating (use "direct access" window of Wintopas) to maximize the 4th pass after setting the wavelength.

b) Now try to get the fourth pass beam at the TOPAS output (adjust M7 and M8). Double the signal with the crystal #2 of the mixer 1 (make sure that the orientation of the mixer is appropriate for the generation of second harmonic signal - SHS). You should get a week red spot. The intensity of the spot should change when adjusting A3. Close A3 to the point where you don't see any halo around the main beam. The spot may get distorted when you open A3 too much.

c) Now, we will adjust the fifth pass. The goal is to make the fifth pass beams collinear and overlapping in time with the 4th pass. Check that the fifth pass pump should be passing in the middle of the optics. Check that the fifth pass pump is collimated; adjust L6 if needed (to get a beam that will cover the crystal face). You should not see any parametric light generated in the fifth pass, when the first passes are blocked. Check that the fifth pass pump beam is parallel to the beams in the first passes and goes through the center of the crystal (adjust M10 and M11 if needed).

d) Overlap the seed beam (fourth pass) with the pump on M11. To do so, block the pump and look on the card before M8 to see the 4th pass seed spot. Then, unblock the pump and check the overlapping of the pump with the seed. Adjust M7 to optimize the overlapping visually.

Notice that we want to align the fourth pass with the fifth pass and not the fifth pass with the fourth pass. In other words, we fix the fifth pump and we adjust the fourth pass seed beam.

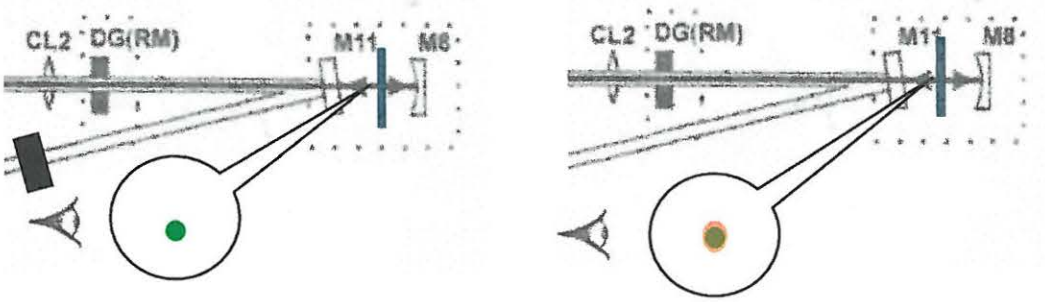


Fig.14: Top view of the spatially overlapping between the seed and the pump. LEFT: when the pump is blocked, one can see the seed from M7 (green). RIGHT: when the pump is unblocked, one wants to overlap the pump (shade red) with the seed spot.

e) The second step to optimize the spatial overlapping is to check at 1- 2 m distance away from the TOPAS (usually one can see a week blue spot that is SH of the pump and overlap it with the red spot- SH of the signal). Move Delay 2 (use amplifier slide bar in "direct Access" window of Wintopas) to get rid of the amplification in the 5th pass if you have any. Adjust M8 to maximize the overlapping (max. intensity of output). Use a power meter at the output of the TOPAS to optimize the spatial overlapping.

Notice that the mirror M8 control only the mirror M8, but if one touches M10, both mirrors M10 and M8 will be adjusted.

f) Now that the spatial overlapping is done, adjust the delay 2 (ref. fig. 11) in order to overlap in time (maximum of intensity at the output of the TOPAS). First, use visual maximization, and then, use a power meter to maximize the time overlapping. BTW, double-check the optimization of the spatial overlapping.

Notice that usually one can find few points with week amplification besides the two strong ones while adjusting delay 2. Two positions of the delay2 (separated by ~ a full turn of the delay2 knob) give the highest output power. The first point comes then the signal is overlapped in time with the pump and the second - when the idler is overlapped with the pump (signal and idler pulses are separated in time in TD). The first one usually gives a higher output energy and stability.

PART III: Calibration of the TOPAS

At this stage of the procedure, we want to achieve the following:

- **Tell the computer what are the positions of the motors**
- **Verify and optimize the offsets of the different motors as regard to the new optic position inside the TOPAS.**
- **Set a table of the different WL and the associate power.**

Repositioning the motors

So far, we manually (or using "direct access" window of Wintopas, the TOPAS operation software) changed the position of every motor during the alignment procedure. Therefore, the computer "doesn't know" anymore the position of some motors (in terms of angle or motor steps). Remember that at this stage, one should have maximized the TOPAS output by adjusting manually (or using "direct access" menu) the crystal, grating, delays, and mixers.

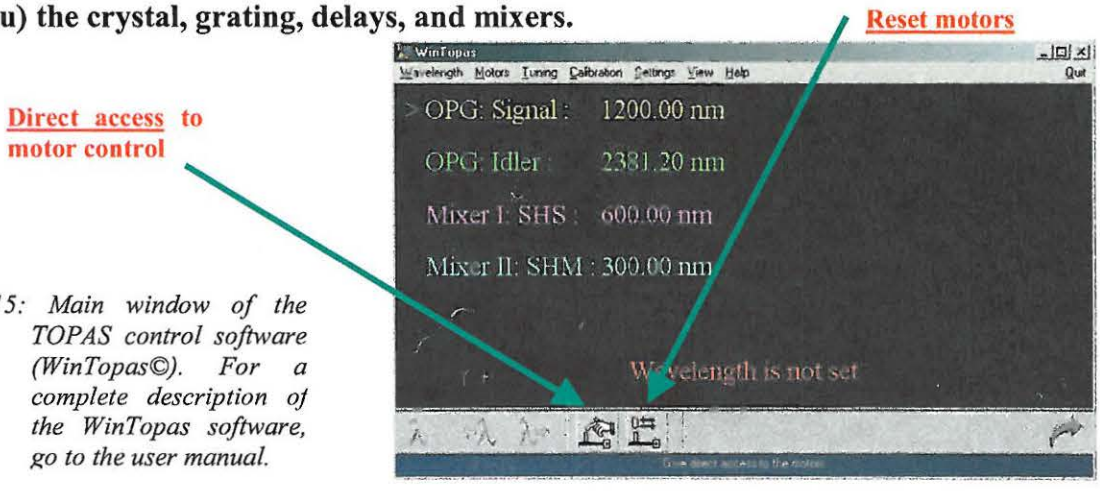


Fig.15: Main window of the TOPAS control software (WinTopas©). For a complete description of the WinTopas software, go to the user manual.

a) Since we do not want to loose lasing of the TOPAS, we cannot reset all the motors at once (we would reset too many parameters at once). So, we will rather proceed one by one (even if some motors have not been touched by hand, this is a good point to double-check the motor positions).

   i) Remember the approximate position of M10. Reset Amplifier Delay 2 motor using the reset menu *(motors/reset motors)* of the TOPAS software (see fig.16).

   ii) Using the Direct Access menu *(Motors/Direct access, ref. fig.17)* at the bottom of the main window (ref. fig.15), adjust (using the arrow bar) the Amplifier Delay 2 motor until the maximum power at the output of TOPAS is regained. Then, the computer knows the position of the Delay 2 motor.

   Notice that the use of a power meter could be helpful in order to optimize the power at the TOPAS output.

   iii) Repeat the same process ((i) and (ii)) for the motor of the crystal and the grating.

   iv) Simply reset the motor the mixer I (and then the mixer II when the WL desired requires its use). Do not go to (ii) for these motors since the alignment did not affect those motors.

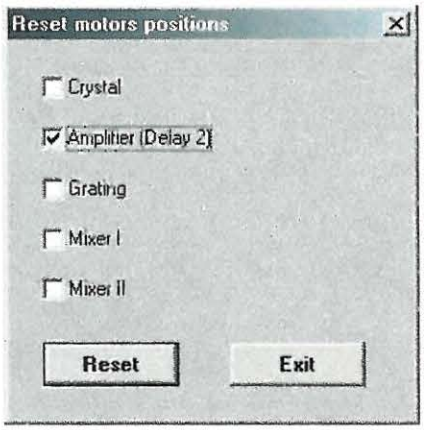


Fig.16: Reset motor menu. Here, each motor can be reset individually by checking the appropriate box.

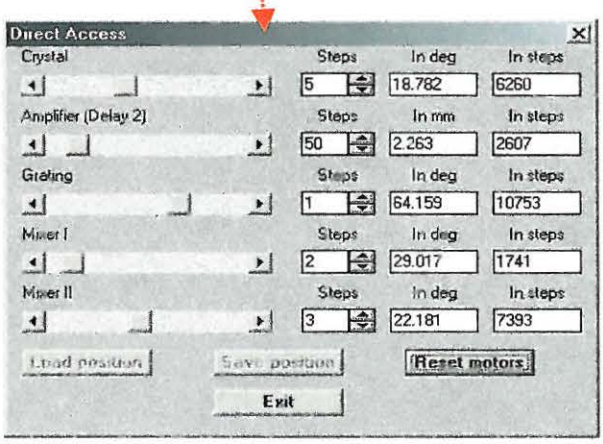


Fig.17: Direct Access to the motor menu. Here, each motor can be set manually.

Optimization of the offsets

Now, we want to find out if there is a difference between the previous calibration and the one that will match the current optics setting of the TOPAS. Such difference is express in terms of offsets for the different motors. So, in a first time, one will calibrate the OPG motors (*O*ptical *P*arametric *G*enerator elements: crystal, grating and amplifier delay 2) by using only ONE WL for the purpose of the calibration. Then, we will calibrate the mixer motor separately using a different WL for each tuning file (refer to user manual for more explanation about tuning files). One will need a spectrometer (exact wavelength calibration of the spectrometer is important) and a power meter to accomplish the OPG calibration.

OPG

Notice here that we choose a WL of 1300 nm for this procedure for simplicity purposes. One could choose to use any other WL if desired.

a) Using the WL setting menu *(Wavelength/Set wavelength)*, set the WL at 650 nm (SH of 1300 nm). Opening the Direct Access menu, take note of the current motor positions (in deg or mm, not steps). These will be used to calculate later the offsets so as to base the new calibration on the last one.

b) Block the fifth pass pump and arrange the spectrometer to measure the signal wavelength after the fourth pass (one can measure SH of signal).

c) Assuming that the TOPAS setting are close to optimum (the grating should be at least in good order), adjust the crystal angle and the grating angle alternately using the 'direct access' window to get exactly 1300 nm wavelength (650nm if using SHS) and max spectral intensity at that wavelength.

Notice that the SHG crystal position may influence the wavelength. Make sure that the Mixer 1 is also optimized for 650 nm.

d) As regard to the grating angle, use the appendix table (ref. user manual, p. 45-48) to get an idea of the angle of the grating for a signal @ 1300 nm (or equivalently, @ SHG 650 nm).

Notice that the grating can diffract a particular WL at different angle. This is called diffraction orders. Note that the TOPAS grating operate below an angle of 70° and that the angular motor range is about 40°. Therefore, during the alignment procedure (Part II), one should choose approximately the right order of diffraction in order to be able to fine adjust the grating using the motor in this section.

IF YOU ARE NOT SURE ABOUT THE GRATING ORDER: One way to set the grating angle is to start by placing the grating at 90° of incidence, and then, turn the grating towards smaller angles until it reaches the highest order (that allow lasing). This can be continued to reach even lower orders…

Notice also that the higher diffraction order used to set the grating angle, the better will be the spectrum (as long as the angle is ≤70°). However, if one wants to get a little higher energy per pulse, the diffraction order should be lowered. Notice also that if one wants to calibrate using the idler WL, the following relation should be used to calculate the angle of the grating to be set.

$$\alpha = \sin^{-1}\left(\frac{m \cdot \lambda \cdot d}{2}\right)$$

with d = 300 lines/mm, is the grating parameter.

E.g. *For a signal at 1300 nm, the following angles are possible corresponding to the different diffraction orders (ref. table p.47, user manual):*

Diffraction order:	1	2	3	4	5
1300	*11.24*	*22.95*	*35.80*	*51.26*	*77.16*

For the idler WL = 2065.86 nm, different angle can be found using the previous equation.

E.g. For Idler = 2065,86 nm, α = 18.05°, 38.30° and 68.38° for the diffraction order 1, 2 and 3 respectively.

So the highest order one reaches when going down from 90 deg corresponds to 77.16 deg. Notice that one always wants to catch the signal order, not the idler. Lets say we want to get the 4 order for the signal. Then we need to miss two bursts in topas output power (one at 77.16, second at 68.38) and stop at the third when turning the grating from ~90 deg.

e) Once the optimum grating angle is set (part c), go to calibration menu (ref. fig.18) (*Calibration/correction*) and then, enter the new grating position value in deg. so that the software can calculate the difference between the current calibration and the previous one and set a new offset relative to the old calibration.

Notice that only the real value (position) has to be entered. The offset is automatically calculated once the correction updated.

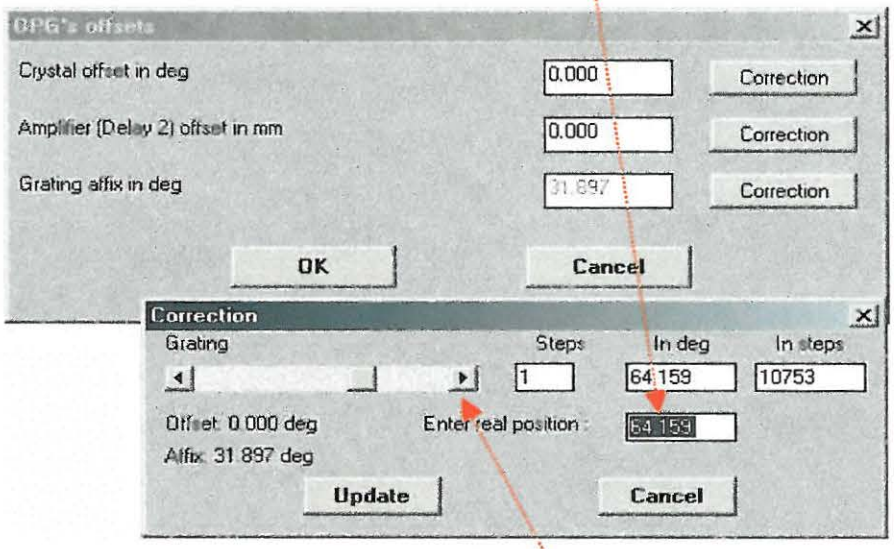


Fig.18: Calibration menu that allows one to enter offset corrections for the grating (OPG in general).

f) Remember the crystal position in deg from 'direct access window". Set the WL at 1300nm (650 nm) *(Wavelength/Set wavelength)*. Go to calibration menu, in the crystal offset correction menu, and then, using the arrows, get the remembered number in the deg box. Update the changes. Alternatively one can calculate the offset subtracting the old crystal motor position from the new and enter the value into 'crystal offset in deg' box (OPG offsets). Then, enter the real value of the delay 2 position and then update the value to calculate the offset of the delay 2. Proceed similarly with the crystal angle.

Notice that one should take note the of previous position values before to update the value in case that a manual calculation is required.

At this stage, it would be important to make the following verification. Using a spectrometer, check that the fifth pass amplifies the same wavelength as generated in the fourth pass:

i) Block the fifth pass pump and measure the signal wavelength after the fourth pass (one can measure SH of signal).

ii) Open the fifth pass pump and measure TOPAS output signal wavelength. Tweak the horizontal adjustment knob of M11 to get the signal wavelength exactly the same as the fourth pass signal wavelength.

Before to proceed with the mixers calibration, one should try to set a different WL for the signal and verify that the motor positions set by the computer correspond to the optimum positions. To do so, check the effect of changing manually (direct access) the motors position on the output power.

Mixer I

a) Since the mixer I motor has already been reset previously, the calibration of mixer I can follow the basic steps described in a), b), c) and e) of the previous section on OPG's. Use the Calibration menu to set the offset (ref. fig. 19).

Notice here that one will need to make the calibration (offsets) for a WL that is different for each tuning file. That means that there is a different offset value (for the mixer I) for each of the tuning file.

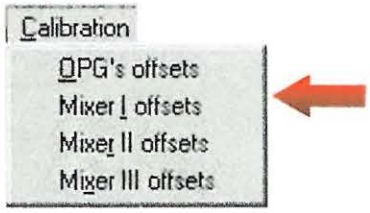


Fig.19: Calibration menu that allows one to enter offset corrections for the Mixer I and the Mixer II (Mixer III is not available).

Mixer II

a) Similarly for the mixer II.

Calibration table

Now that the offsets are known, we want to update the table of the WL Vs Power of Idler and Signal. We refer the reader to the calibration files (corresponding to the tuning files) for an updated version. Our goal here is to provide with a value of TOPAS output power Vs WL, and this, for the different WL ranges covered by the different tuning files. A spectrometer (fiber coupled) will be, once again, needed to achieve this task.

Notice that by placing the fiber end behind a business card (for diffusion purpose), one would get enough light for the spectrophotometer and yet, will avoid saturation.

a) Starting at the bottom of the WL range, 280 nm, set the appropriate WL tuning file in the WinTopas software.

b) Then, set the first WL listed on the table using *Wavelength/set wavelength* menu. Once the TOPAS is set at this WL, verify the WL using the spectrometer and read the power of the Idler+ signal on a power meter place before the fiber end.

c) Set the next WL on the table that is still included in the same tuning file.

d) Repeat steps a), b) and c) until the entire WL range is covered (all tuning files covered).

Abbreviation significations

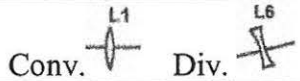
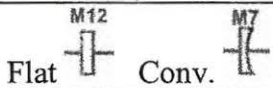
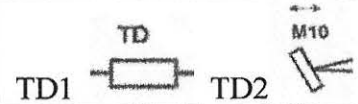
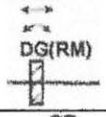
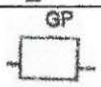
Sample abbreviation	Signification	Sample symbol
A1	**A**perture	
BS1	**B**eam **s**plitter (not all 50:50)	
L1	Diverging or converging **l**ens	
CL1	Cylindrical **l**ens	
M12	Flat or converging **m**irror	
CM1	**C**ylindrical **m**irror	
PR	**P**olarization **r**otator	
NC	**N**onlinear **c**rystal	
TD	**T**ime **d**elay	
DG	**D**iffraction **g**rating	
GP	**G**lass **P**late	
. . . . .	Main assembly element	

Table.A1: Significations of the abbreviations used on the TOPAS layout.

APPENDIX II: Additional procedures

In the case that one HAVE TO modify the beam profile or the beam size/divergence of the TITAN pump beam entering the TOPAS, the collimation lens have to be adjusted inside the TOPAS to compensate for the new seed beam parameters. The following procedures are related to that particular situation.

First three passes collimation adjustment

When one change the beam divergence and the beam size of the TITAN, one ened to adjust L1 to make sure that there will have enough intensity on the crystal to produce superfluorescence after the third pass.

1) The lateral adjustment of L1 (horizontal position on the base slot) will change the size of the beam on the crystal. We want to get enough intensity to get superfluorescence but yet, not to burn the crystal. Therefore, by precaution, scan SLOWLY from left to right (when increasing the intensity) (ref. fig. A2)

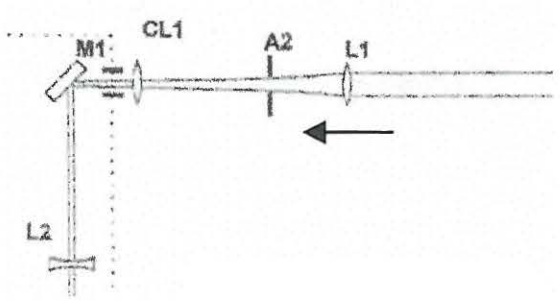


Fig.A2: Top view of adjustment direction of the lens L1 in order to change the intensity of the beam on the crystal.

2) Make sure that the vertical alignment of the first and third pass still good while scanning the L1. Also, if the beam is too wide or blurry on the card before CL2, that means that the beam is too intense on the crystal. There is two possible solutions: close A2 a little until the beam looks good, **or** move L1 more carefully and more finely to get the right position that will allow the right intensity on the crystal.

   Notice that if the lens is already aligned and the beam is slightly blurry, try using the aperture. However, if a major alignment of the beam is required, try moving the lens to the appropriate position.

Fourth pass collimation adjustment

For the same reasons, if the beam parameters are changed in the TITAN, the collimation lenses in the fourth pass must be adjusted.

1) Adjust first L3 laterally on the base slot in order to get ~ 1mm wide beam (same size than first pass) before M5 (on card). Then, if L3 is not enough to focus properly, adjust in the same way the lens L3'.

   Notice that if the focus is too much, one can decrease the intensity of the beam using A3 to lower the power on the crystal (to avoid burning). Remember that the beam size of the fourth pass has to be small for two reasons: first, to have intense enough to pre-amplify the seed and second, to select a limited spectrum of the diffracted light from the grating.

Fifth pass collimation adjustment

For the same reasons, if the beam parameters are changed in the TITAN, the collimation lenses in the fifth pass must be adjusted.

1) Adjust first L6 laterally on the base slot in order to get the beam collimated (check that the beam size does not change over distance)

QUANTRONIX

CUSTOMER ASSISTANCE REPORT

017973

P.O. #

Dates Involved 1 12/19/02 2 12/20/02 3

SHIPPED AT	BILL TO
ACCOUNT: Maglab, FSU	ACCOUNT:
ADDRESS: Tallahassee, FL	ADDRESS:
CITY: Tallahassee STATE: FL ZIP:	CITY: STATE: ZIP:
PERSON TO SEE: Dr. Young Dah Jho	PERSON CALLING:
PHONE: 850-645-3265 x	PHONE: x

MODEL	SERIAL #	INST	REP	P.M.	MOD	UG	W	C	M	ALL N/C	PART N/C	PA	OS
TOPAS	134												

REASON FOR CALL:

TOPAS Installation and custmor training (Basic)

PROBLEM(S) FOUND:

The fiber Osc in Clark Amplifer is not working very well. could not be mode-locked..

CORRECTIVE ACTION TAKEN:

1) Finish the TOPAS setup (Basic) and calibrate it. However, did not optimize the TOPAS very well Because of the problems of Clark Amplifier (waste one day).
TOPAS pumping at 772nm @ 1KHz at 0.8mJ, maximum output, ~0.1~0.15mJ

2) Custmor training.

THIS REPORT IS ___ OF ___ REPORTS	SEE ATTACHED SHEET	Y	N	EXPENSE REPORT #

PARTS & LABOR

ITEM	PART NUMBER	DESCRIPTION	QTY	UNIT PRICE	EXTENSION	ACCT.
1						
2						
3						
4						
5						

DATES →	1	2	3	TOTAL TRAVEL EXPENSE		TOTAL PARTS	
HOURS ↓				TOTAL TIME ↓		HRLY RATE ↓	
TRAVEL					HRS x	=	
SHOP					HRS x	=	
ON SITE					HRS x	=	
OVERTIME					HRS x	=	
					SHIPPING →		
							TOTAL CHARGE

FIELD ENGINEER SIGNATURE

X CUSTOMER SIGNATURE

WHITE - HOME OFFICE GREEN - LOCAL OFFICE CANARY - ENGINEERING GOLD - CUSTOMER

Pump CPA-2001, λ_p = 773.5 (774.1) E_{TOPAS} = 0.75 mJ
$\Delta\lambda$ = 5.5 nm ⇒ 92 cm⁻¹ (163 fs)

Topas-02236

λ_s=1280 nm   s+i+shs = 189 μJ   s+i+p = 527

18.731 (6243) 5.651 (6510) 22.58 (9180) 2.833 (7370)

λ = 1100

16.766 (5538) 5.621 (6475) 18.27 (2702) 20.033 (7205)

12/03   773 crv (14/03)

λ_s	$E_{s+i+shs}$	E_{s+i}	λ_s	$E_{s+i+shs}$	E_{s+i}
1100	122	130	1400	181	203
1120	149	159	1420	186	208
1140	164	181	1440	189	209
1160	170	189	1460	190	208
1180	169	190	1480	188	202
1200	176	197	1500	188	201
1220	180	203	1520	187	211
1240	186	208	1540	184	212
1260	186	211	1560	185	220
1280	186	210			
1300	183	207			
1320	184	207			
1340	188	204			
1360	184	201			
1380	180	203			

Tilt of pump pulses. Vertical / 5 mm (→ 16 fs, 80 μm)   tilt beam ~ 80 μm / 5 mm

Horizontal / 5 mm (30 μm)   ~ 50 μm / 5 mm

[illegible] ~ 3.3 fs

λ_p = 774.1 nm   SH and SFS [illegible] this λ.

Crystals #2, 3, 5, 6 orientation OK.

13/03 Pump to Topas ~ 720 μJ @ 774.1 nm

9 - 2.5 = 6.5 μJ @ 4 μm (AgGaS₂)

Orientation ~~for~~ of #829 OK.

• Don't change Grating & Crystal.

SH1774.crv (λ_D = 775.6 nm $\frac{1}{b}$)

λ_{SH1}	$E_{SH1}+b$	b	E_{SH1}	λ_{SH1}	$E_{SH1}+b$	b	E_{SH1}
776.3	60.5	1		980	27.9	4.4	
780	58.8	0.9		1000	25.5	4.7	
790	54.4	0.9		1020	25.4	7.1	
800	51.6	0.9		1040	25.8	10.4	
820	48.7	1.0		1060	25.0	12.1	
840	47.2	1.2		1080	26.2	14.3	
860	42.7	1.5		1100	34.7	26	
880	39.0	2.0					
900	35.7	2.4					
920	34.1	4.5					
940	32.4	5.7					
960	31	5.5					

SHS774.crv

λ_{SHS}	$E_{SHS}+b$	b	E_{SHS}	λ_{SHS}	$E_{SHS}+b$	b	E_{SHS}
550	39	2		680	70	7	
560	52	3		690	70	8	
570	63	3		700	69	9	
580	70	2.5		710	72	10	
590	71	2.5		720	73	10	
600	72.7	4		730	71	9	
610	77.5	5		740	69	8	
620	79	6		750	62	2	
630	75	5		760	62	1	
640	74	4		770	62	1	
650	71	4		775	59	1	
660	71	5					
670	72	6					

516.933
517.202

SF774.crv

λ_{SF}	$E_{SF}+b$	b	E_{SF}	λ_{SF}	$E_{SF}+b$	b	E_{SF}
455	82.5	6		525	43	8	
460	101	6		530	45	6	
465	118	8		535	44.7	6	
470	116	11		540	45	6	
475	110	8		545	45	8	
480	104	10		550	48	10	
485	97	11		555	49	10	
490	93	10		560	52	10	
495	86	7		565	56	8	
500	84	6		570	61	7	
505	82	7					
510	77	8					
515	83	9					
SF5 516.93	83	10					
516.933	83	10					
SF1 517.204	52	9					
520	49.7	9					

4HS774.crv

λ_{4HS}	$E_{4HS}+b$	b	E_{4HS}	λ_{4HS}	$E_{4HS}+b$	b	E_{4HS}
275	10.2	4.7		340	20.4	2.3	
280	14.3	4.2		345	19.7	2.6	
285	18.5	3.9		350	19.5	3.0	
290	21.5	3.2		355	20.9	3.5	
295	21.5	2.8		360	21.8	4.0	
300	21.2	2.3		365	21.9	4.5	
305	25.2	3.6		370	22.5	4.4	
310	25.0	2.9		375	22.2	4.7	
315	24.5	2.4		380	21.7	4.3	
320	23.3	2.1		385	21.4	4.5	
325	21.5	2.0		387.5	22.2	4.6	
330	20.8	2.0					
335	21.0	2.3					

4HI774.crv

λ_{4HI}	$E_{4HI}+b$	b	E_{4HI}	λ_{4HI}	$E_{4HI}+b$	b	E_{4HI}
388.2	22.1	3.9		440	13.8	2.3	
390	25.1	4.6		445	13.0	2.0	
395	21.3	4.5		450	12.3	1.9	
400	20.3	4.3		455	11.4	1.8	
405	19.7	4.1		460	10.4	1.8	
410	19.5	4.0		465	9.5	1.8	
415	19.1	3.8		470	8.9	1.9	
420	18.6	3.6					
425	17.3	3.2					
430	16.1	2.9					
435	14.9	2.6					

258.466
258.601

SHSF774.crv   } separated (by prism)

λ_{SHSF}	E_{SHSF}	λ_{SHSF}	E_{SHSF}
227.5	5.7	258.601	3.1
230	7.6	260	2.8
232.5	11.5	262.5	2.4
235	12.3	265	2.64
237.5	12.8	267.5	2.56
240	12.4	270	2.58
242.5	11.8	272.5	2.33
245	11.1	275	2.40
247.5	10.2	277.5	2.47
250	10.3	280	2.67
252.5	10.3	282.5	3.15
255	9.1	285	3.15
257.5	9.2		
258.466	9.0		

Evening. 175 mJ @ 5+4 Mix 1 + Mix 2 @ 270nm (pump blocked)

14/03/2003

DF1774.crv (Ag Ga Se)

λ_{DF}	$E_{DF}+b$	b	E_{DF}
2600	25.0	18.2	
2800	21.8	14.2	
3000	18.1	10.0	
3200	15.5	7.5	
3400	12.7	5.9	
3600	11.2	4.6	
3800	10.2	3.8	6.4
4000	8.9	3.3	5.6
4200	7.5	2.9	4.6
4400	7.6	2.6	5.0
4600	7.1	2.3	4.8
4800	6.4	2.2	4.2
5000	5.8	2.0	
5500	4.6	1.5	
6000	3.7	1.14	
6500	3.0	0.97	
7000	3.0	0.87	
7500	3.05	0.83	
8000	3.01	0.79	
8500	2.78	0.78	
9000	2.52	0.78	
9500	2.37	0.81	
10000	2.31	0.83	
10500	2.25	0.86	
11000	2.15	0.88	
11500	2.06	0.94	
12000	1.96	0.97	
12500	1.85	1.05	
13000	1.73	1.09	

DF2774.crv (CaSe)

λ_{DF}	$E_{DF}+b$	b	E_{DF}
4500	6.65	1.60	
5000	5.60	1.30	
5500	4.60	1.1	
6000	3.75	0.83	
6500	3.10	0.74	
7000	3.00	0.69	
7500	3.07	0.69	
8000	3.07	0.65	
8500	2.88	0.61	
9000	2.65	0.62	
9500	2.50	0.62	
10000	2.40	0.61	
11000	2.27	0.63	
12000	2.22	0.70	
13000	2.18	0.76	
14000	2.12	0.82	
16000	1.95	0.89	
18000	1.76	0.91	
20000	1.54	0.93	
22000	1.36	0.93	
24000	1.21	0.92	
26000	1.09	0.89	

System Components

CPA-2001 User Manual, Version 4.2

Latest Upgrade: October, 2002

This manual contains information on the subsystems forming the CPA-2001 Laser System: SErF fiber oscillator, pulse stretcher, ORC-1000 frequency-doubled Nd:YAG pump laser, regenerative amplifier, and pulse compressor.

CPA MANUAL.

Serial # from Clark MXR

=> 1323

Copyright Notice

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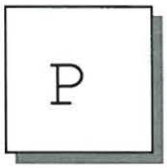
Graphic Symbols Explained

The following graphic symbols are used throughout this manual to draw your attention to situations or procedures that require extra attention. They warn of hazards to your eyesight, damage to equipment and necessary performance specifications.



Performance Specifications. You should follow these instructions without deviation.

Serious bodily harm, including permanent loss of vision may result from exposure to radiation either present in the area, or radiation that may be created when executing the alignment step detailed along side it. Eye protection required.

Graphic to draw your attention to a warning or important notice.

Wear protective gloves when handling sensitive optical components. Skin oil on optical components may make them worthless.

Electrical Hazard.

Wait – there is a warming-up period. Do yourself a favor and wait.

Post warning signs that alert others to the presence of laser radiation.

Authorized personnel only! Assemble and operate this system in an enclosed room.

1 Eye Safety

The lasers you will be working with are sources of intense optical radiation. Their safe use depends on your awareness of their potential hazards and taking precautions to avoid any bodily harm.

At almost every stage of the system alignment procedure, the intensity
of the beams from the ErF/SErF fiber oscillator, the Ti:Sapphire regenerative amplifier, and its frequency-doubled Nd:YAG pump laser can cause serious damage to the eye, including permanent loss of vision, when viewed directly or when reflected off another object.

The radiation generated and amplified by the Ti:Sapphire is in the near IR wavelength range where the sensitivity of the retina is minimal. When the Ti:Sapphire laser is operating in the near infrared, the weak appearance of the beam may **mislead** you into believing it is of low intensity and therefore of little concern. However, permanent loss of vision can still occur.

The various wavelengths, pulse energies, and operating power emitted by the lasers forming the CPA-2001 system are listed in Table 1-1. Use this table and good sense to decide what level of eye and skin protection is needed.

- **Use of controls or adjustments or performance of procedures other than those specified in this manual may result in hazardous radiation exposure.**

Table 1-1
Laser parameters affecting the user's safety

Laser	*Wavelength (nm)*	*Power*	*Pulse Energy*
ORC-1000 Nd:YAG	532	< 65 W	< 25 mJ
Regen. Amplifier	775	< 5 W	< 5 mJ
ErF Fiber Laser	1550	< 0.2 W	< 10 nJ
SErF Fiber Laser	775	< 20 mW	< 1 nJ

- **Post the laser parameters (shown in the preceding chart) near the laboratory to alert everyone to the presence of laser radiation.**

Read the safety instructions of the CDRH certified Nd:YAG laser (used to pump the regenerative amplifier). Incorporate the safety recommendations into your standard practice.

Please refer to Chapter 9 for the location of safety labels affixed to the CPA-2001 housing.

- **When setting up or aligning the system or subsystems, KEEP ALL BEAMS BELOW EYE LEVEL. Never look in the plane of propagation of the beam, or pass through it while bending down without first turning off the laser.**

The beam from the laser system can cause permanent loss of vision even when it appears to be of a low intensity! Intense coherent and incoherent radiation is emitted from the Ti:Sapphire rods when they are being pumped by other lasers. Avoid all direct exposure to the laser beams. Wear LASER SAFETY GOGGLES.

Remember that safety goggles *can be a hazard as well as a benefit.* To protect the eyes from the laser beam, the goggles must attenuate to the point where the beam is no longer visible. Therefore, the user can be exposed to **flesh burns** or **clothing fire** without seeing it happen. *Be aware of this potential.* Follow the specific recommendations called for in this manual at various stages during the alignment procedure.

- **Assemble and operate this system in an enclosed room. Periodically inspect the area for stray beams and reflections. Block those that propagate outside of the work area during assembly and alignment. Prevent all uncontrolled reflections.**

- **When servicing the system do not wear jewelry (*for example,* rings, chains, etc.) that might pass through the laser beam line. Uncontrolled reflections may result!**

The laser beams can remain collimated over large distances and remain a hazard far from the original source. Clearly mark the door to the room with warning signs and interlocks connected to the two pump lasers to prevent accidental exposure to the beams.

- **Post warning signs that alert everyone to the presence of laser radiation. Please ask Clark-MXR, Inc.'s service department if you need signs.**

Do **NOT** operate the system while untrained personnel are present. Warn anyone in the area where beams are located of the dangers associated with laser beams. **Verbal warnings** help to ensure that others in the area are *not* injured by stray radiation.

- **Limit access to the equipment to trained personnel who have a need to use it.**

The Eye Protection Required symbol warns you that **serious bodily harm** may result from exposure to radiation either present in the area, or radiation that may be created when doing the step detailed along side it (*see also*, Graphic Symbols Explained at the beginning of this manual).

- **Observe and understand the symbol that follows.**

- **Remember, safety is your responsibility! Follow these safety procedures when working with this product.**

2 Site Preparation

2.1 Laser Room

The CPA-2001 system is designed to operate under standard laboratory conditions.

- The laboratory site must be easily accessible, because some large pieces of equipment will have to be moved to the site, including the optical table(s) and the various laser power supplies.

- Water and electricity must be available (see below).
- The room temperature must be stable to ± 2° C, and the humidity level must be maintained at all times below the condensation point.

- The site must be reasonably free of sources of vibration.
- The site must be clean. The cleaner the facility, the less often cleaning of the optics will be required.

- The airflow in the room (air conditioning) must be directed away from the lasers. Turbulent airflows will disturb the laser system and degrade its short-term stability.
- The laser table must be well lit. If an overhanging platform is located above the table, it may be necessary to install some additional lights. The light level control must be easily accessible as some of the alignment steps call for a darkened room.

- The supporting surface temperature must be stable to ±2° C.
- The supporting structure surface must provide some type of anchorage points located on a regular basis (such as a 1" or 25 mm grid).

- For safety, the laser site access must be restricted (see Chapter 1, Eye Safety).

2.2 Utility Requirements

2.2.1 YAG Laser Requirements

Electrical Connections

Voltage: 208-240 VAC, line to line single phase
(line to neutral: Europe)

Frequency: 50 or 60 Hz

Current: 40 A

Temperature Stabilization Loop Requirements

Electrical

Voltage: 110-120 VAC (grounded 3-prong)

Frequency: 50 or 60 Hz

Current: 10A

- **Note that additional outlets will be needed for the power meter, the oscilloscope, the autocorrelator, etc.**

2.2.2 Water Requirements

The external water flow (intermittent) is controlled by a built-in thermostat. The ORC power station contains an internal closed circuit heat exchanger, which must be filled with five (5) gallons of distilled water for the actual cooling of the laser head.

External Water Loop

Flow: 3.5GPM

Temperature: 59°F-72°F (15°C-22°C)

Pressure: 30 to 50 psi

Back-pressure: none (i.e. opened drain)

Internal Water Loop

De-ionized Water: Initially requires 5 gallons

Temperature Stabilization Loop Requirements
Water (Internal Loop)

Water Capacity: 6 liters distilled water

2.2.3 Nitrogen Requirements

The CPA-2001 Laser System provides a nitrogen port for purging the entire system with clean, oil-free and dry Nitrogen. The Nitrogen over pressure can be used to keep the optics clean of dust contamination (especially in the regenerative amplifier) and to eliminate any residual amount of light absorption by water vapor. *For optimum long-term performance stability and optics maintenance, we recommend the purging of the CPA-2001 with dry Nitrogen at all times.*

The Nitrogen must be provided at a pressure no higher than 0.2 Bar (2.9 PSI) through a 1/4" OD, 1/8" ID tubing.

2.3 Support Equipment & Supplies

The following equipment/supplies are required to setup, align, and operate the CPA-2001 laser system.

- One **analog** oscilloscope (bandwidth greater than or equal to 350 MHz) to view output beam
- One infrared viewer (FJW Find-R-Scope, or equivalent)
- One analog laser power meter (Range up to 10 watts, with sensitivity equal to or better than 10 mW); Model Molectron Power Max 5100 with head PM10, or equivalent
- One autocorrelator, model Clark-MXR AC-150, or equivalent: The autocorrelator must be able to measure pulses as short as 100 fs at 40 MHz (oscillator) and at 1 kHz (amplifier)
- A set of tools including a wrench set, screwdrivers, a set of U.S. Allen wrenches, a utility knife, a measuring tape, a ruler, and a voltmeter
- A flashlight
- De-ionized and distilled water (see above)

- Nitrogen (see above)
- Optics cleaning supplies include: Spectroscopic or Research Grade Methanol and Acetone, lens tissue, powder-free gloves, several cans of dust-free compressed gas

3 System Overview

3.1 System Layout

The CPA-2001 is a compact, integrated Ti:Sapphire amplified laser system and is comprised of the following physical units:

- Laser Head: 48"Lx20"Wx12"H
- ORC-1000 Power Supply: 38"Lx23"Wx24"H (YAG Laser)
- DT-505 Pockels Cell Driver: 18.5"Lx16.5"Wx6"H
- Temperature Stabilization Unit: 16.5"Lx8.25"Wx22.5"H

The CPA-2001 laser head contains the following subcomponents in a bi-level optical layout design as schematically shown in Figure 3-1 below.

- SErF fiber oscillator
- Pulse stretcher
- Regenerative amplifier
- ORC-1000 frequency-doubled Nd:YAG pump laser
- Pulse compressor

Bottom Level

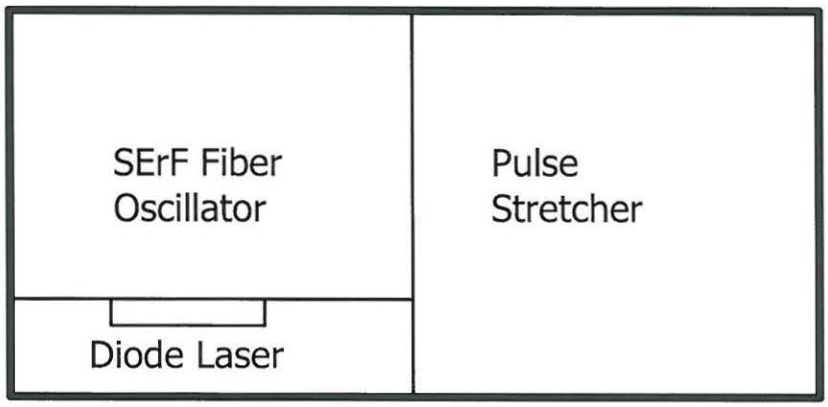
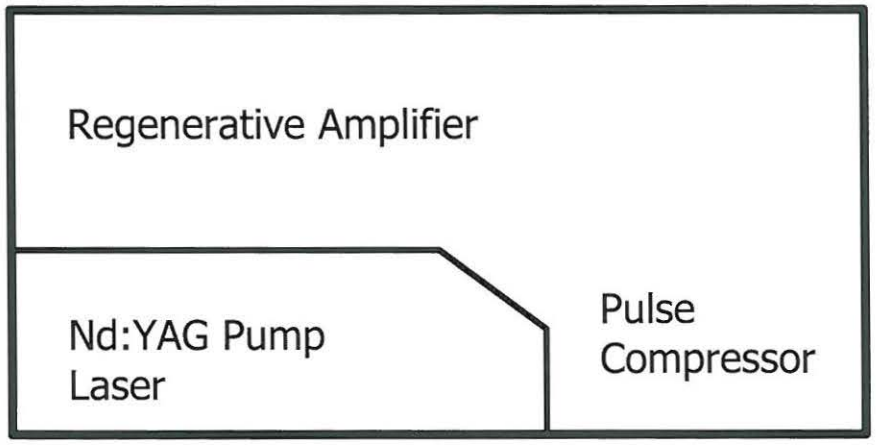


Figure 3-1. CPA-2001 Laser Head Schematic Layout

Top Level



3.2 Initial Positioning and Setup

The weight of the CPA-2001 should be sufficient to keep it in place on most optics tables. The clamps shipped with the unit are provided as a safety measure to keep someone from accidentally pushing the laser across the table. Optics tables are subject to temperature stresses as lab temperatures fluctuate. The CPA-2001 is temperature stabilized and does not expand and contract with room temperature changes in the same way as an optics table. With the CPA-2001 only loosely secured to the table, the table is free to expand and contract under the feet of the laser.

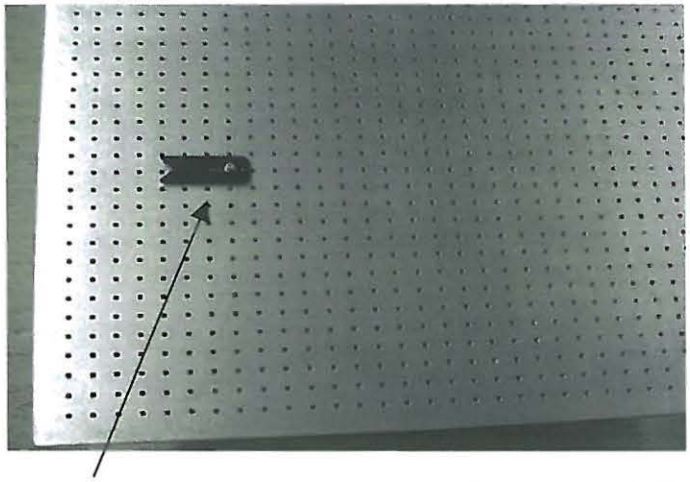
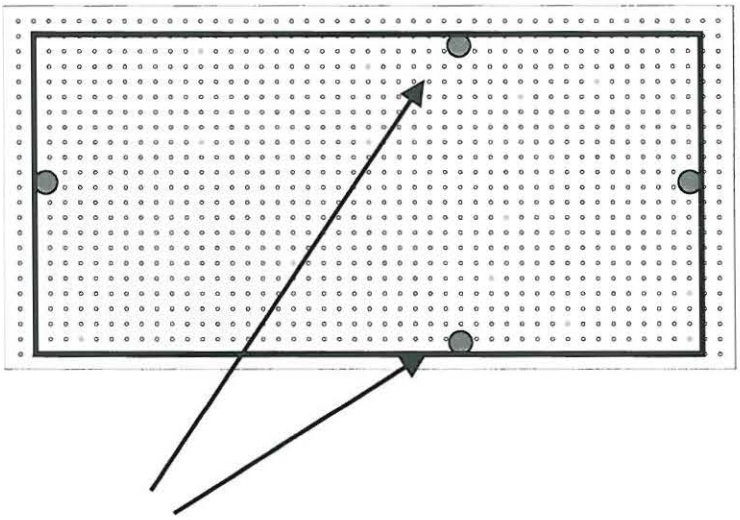


Figure 3-2 Location of first foot clamp (drawing not to scale).

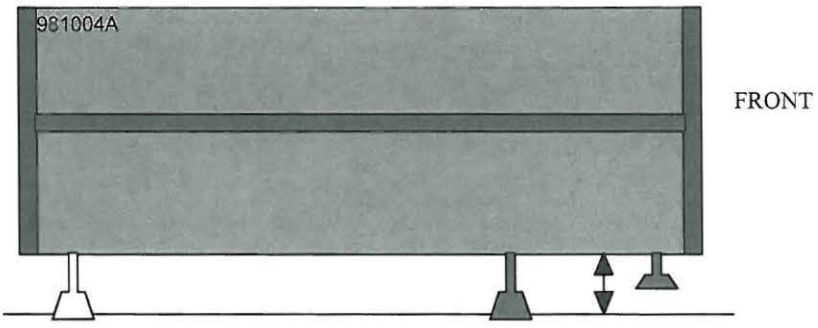
Figure 3-3 Location of second and third foot clamps (drawing not to scale).



Position these clamps *once* the CPA-2001 is positioned on the table

The laser head unit of the CPA-2001 should be positioned on the optical table. Three fixed-height legs and one adjustable leg are provided. Adjust the fourth leg so that it just touches the table surface then loosely tighten the foot clamps. Make sure all four feet are on the table.

Figure 3-4 Location of height adjustable leg.



All of the necessary utility connections are available at the rear end of the laser head unit as illustrated in the figures below.

3.3 Thermal Stabilization of the CPA-2001

Once the CPA-2001 is located on the table, the next step in the setup is the connection of the water circulator to the laser head unit. An overview of the thermal stabilization water loop is shown in Figure 3-5.

The connection sequence is shown in Figures 3-6.

The thermal equilibration of the CPA-2001 may take 24 hours to achieve, and it is important to reach thermal equilibrium before operating the laser system. The water circulator should be set at the factory test temperature, typically 18 +/-1° Celsius (this may differ on some units, see test data sheet).

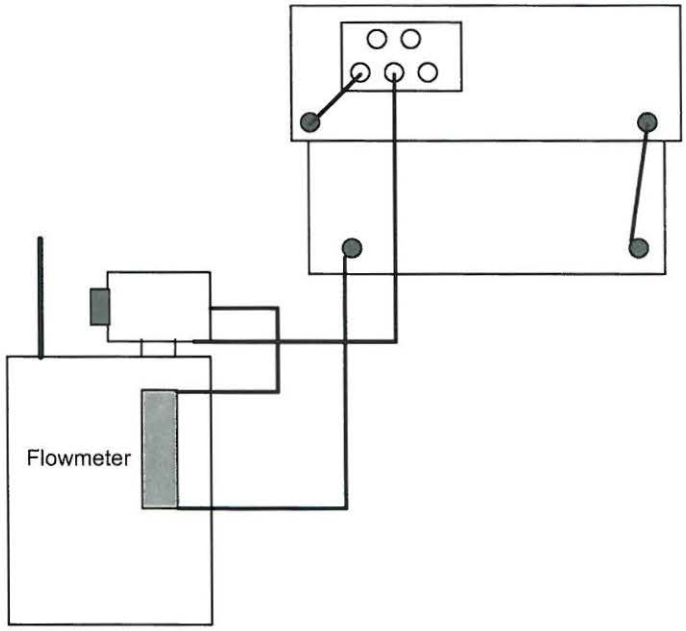


Figure 3-5 Overview of the temperature stabilization loop for the CPA-2001.

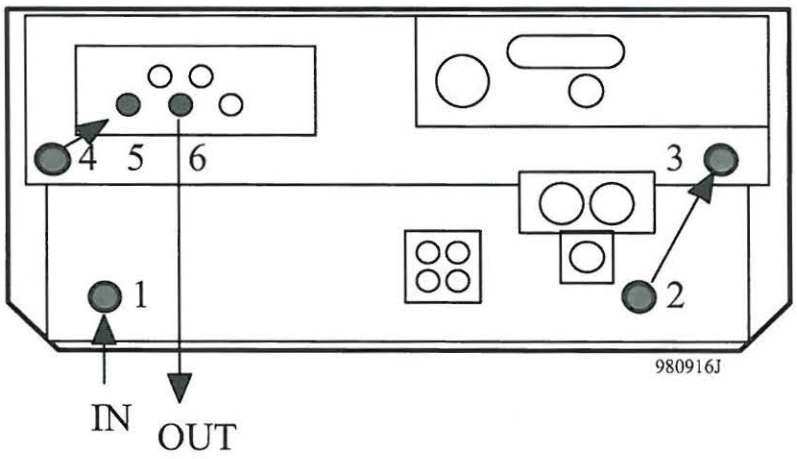


Figure 3-6 CPA-2001 Temperature stabilization connections

3.4 Electrical Connections

The electrical connections sequence is shown here.

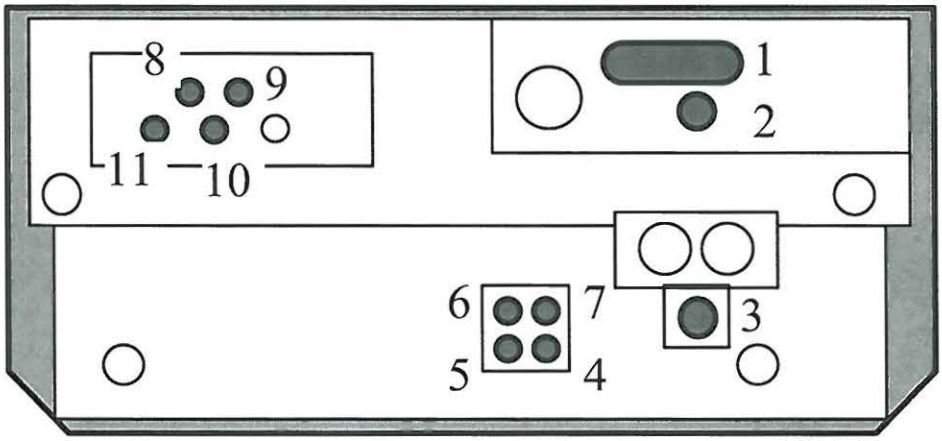


Figure 3-7 Electrical connections for the CPA-2001

Port	Type	Function
1	D-connector	ORC interlock etc.
2	BNC	RF for AO Q-switch
3	Circular, multi-pin (4)	Power for diode laser & PPLN interlock
4	BNC	PPLN temperature monitor
5	BNC	Reservoir for future use
6	Circular, multi-pin (6)	Heater PPLN, thermistor, 12v DC
7	BNC	Monitor mode locking
8	BNC	Monitor amplifier
9	Circular, multi-pin (2)	Power to photodetector

In addition, there is an electrical cord with 6 connectors for the DT-505 Pockels Cell Driver that is a part of the CPA-2001 laser head unit.

- **Once connected, power must be maintained to the ORC power supply at all times.**

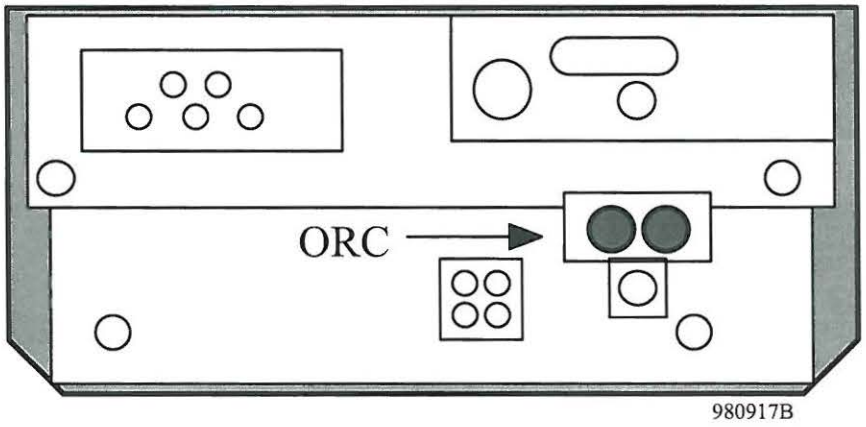
3.5 Cooling YAG Laser

Connect water hoses between ORC (YAG) power supply and CPA-2001 as shown in Figure 3-8.

- **Note that the direction of the flow matters!**

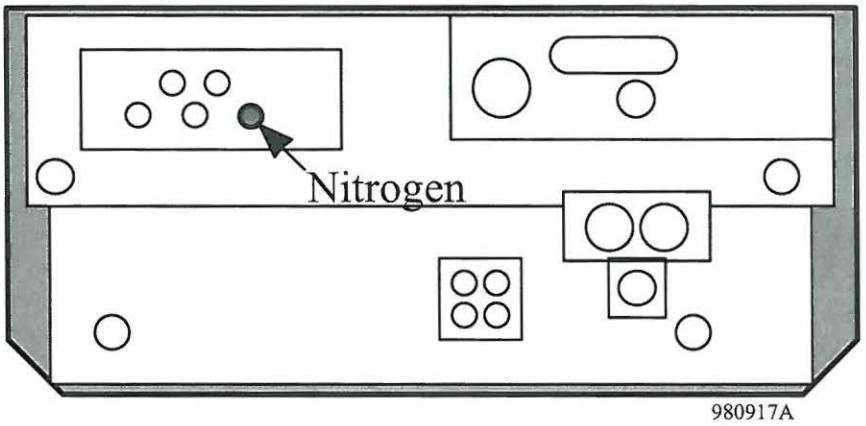
Connect the red-marked hose to the red-marked port. Fill up the ORC reservoir with de-ionized water. (See Chapter 2.)

Figure 3-8 Water Cooling ORC (YAG).



3.6 Nitrogen Overpressure

Figure 3-9 Nitrogen port on the CPA-2001



Connect user-provided dust-free, dry Nitrogen flow (see Chapter 2) to CPA-2001 as shown in Figure 3-9. This last step is not required if the CPA-2001 is installed in a cleanroom.

4 System Operation

4.1 Daily Routine Operating Procedure

The following is a synopsis of the "day to day" procedures for using the CPA-2001 laser system. It is intended for use by those who have received training on the operation of the CPA-2001, and are familiar with the function of the components mentioned.

4.1.1 Start Up Procedure

1. Turn on the external cooling water to the ORC pump laser.

2. Check that the SErF is mode-locked. This can be done by checking the frequency meter on the Q-switch driver located in the ORC power supply. Alternatively, the photodiode output that connects to the RF input of the DT-505 Pockels cell driver can be checked on an oscilloscope. If the SErF is not mode-locked, see the troubleshooting section.

3. Turn on the ORC laser.

   A. Turn on the key switch.

   B. Start the water pump using the pump start momentary contact switch.

   C. Turn on the power supply (rocker switch). Wait until lamp button is completely lit up.

   D. Turn on the lamp by pressing the glowing button. The light should turn off when it is pressed. Repeat as necessary. The Operating current on the amp meter is an indication that the lamp is turned on.

   E. Wait 5 minutes for the ORC to stabilize.

   F. Open the ORC main shutter.

   G. Turn on the ORC feedback (see details in section 5.4.1).

   H. For units equipped with independent injection shutter, open this now.

4. Turn on the H.V. switch on the DT-505 Pockels cell driver.

5. Wait for the system to warm up for 15 minutes. The system should now be operating at the same level as the previous day. If not, see troubleshooting section.

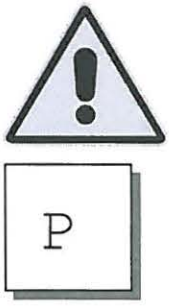
4.1.2 Shut Down Procedure

1. Turn off the ORC feedback loop.
2. Close the shutter on the ORC pump laser.
3. Turn off the H.V. switch on the DT-505.
4. Turn off the ORC power supply (rocker switch next to the lamp start switch).
5. Turn off the ORC key switch.
6. Turn off the external water.

4.1.3 Items To Be Left On

The following items should be left on at all times:

1. Water circulator for thermal stabilization of CPA-2001 system
2. DT-505 main power switch
3. AC power to ORC power supply



- **In the case of power failure or shut down, check that these items are reactivated immediately. If the water circulator is shut off for any reason, then the CPA-2001 needs to thermally equilibrate again after the circulator is turned on. Allow 24 hours before operating the CPA-2001 laser system. If the temperature setting of the circulator is changed, the CPA-2001 may need re-optimization. It is strongly recommended that the temperature of the water circulator remains constant at the factory set value.**

4.2 24-Hour Operation

The CPA-2001 is designed to be able to operate on a 24-hour basis provided proper safety precautions are used and regular maintenance is performed.

5 A More Detailed Look at the CPA-2001

5.1 SErF™ Fiber Laser Operation

SErF is based on the fiber ring "Stretched Pulse" laser developed at MIT by the group of Professors E. P. Ippen and H. A. Haus. The basic design is that of a unidirectional, polarization rotation additively pulse mode-locked (APM) fiber laser which uses Erbium doped fiber as the gain medium. The output wavelength of SErF is centered on 775nm. The system is designed to provide hands off performance once it has been set up in a standard optics laboratory environment. The pump source for the laser is an all solid-state fiber-coupled laser diode operating at approximately 980 nm.

The SErF contains the following components:

1. A laser diode and associated control electronics.
2. An active fiber ring laser.
3. Some bulk optics used for polarization control, output coupling and wavelength control.
4. A compressor to eliminate residual dispersion of the output pulses.
5. A temperature-stabilized periodically poled lithium niobate (PPLN) frequency doubler.

These components have been set to optimize your system's performance prior to shipping, and should not be touched. The fiber ring is sealed in a rigid frame. **Do not** attempt to gain access to this fiber, because doing so will result in damage and void the warranty on this system. However, the user does have limited access to the bulk optics (3), and if it is necessary to adjust these, instructions are included in the troubleshooting section.

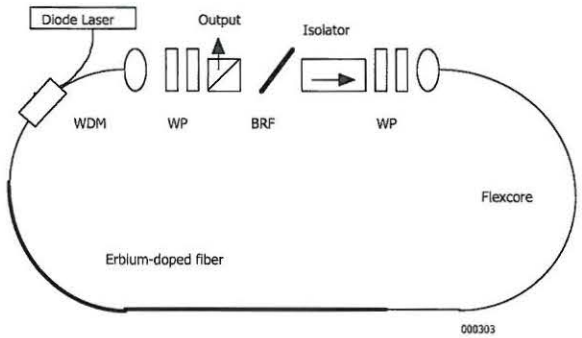


Figure 5-1
The schematic of the fiber oscillator. WP denotes waveplates and BRF denotes birefringent filter.

- **The temperature stabilization loop must be on 24 hours prior to operation of the CPA-2001.**

After installation, the SErF is left on at all times to achieve optimal system performance. The laser diode is telecommunications grade and has a mean lifetime of 20 years, so it is not necessary to worry about "wearing out" the diode.

The diode will remain on unless the ORC power supply is disconnected, or the main power toggle switch, CB1, on the back of the ORC power supply is turned off. If the ORC power supply has been disconnected or turned off, the SErF may require up to two hours before standard operation is achieved.

- **The temperature stabilization loop must be on *at all times* for the CPA-2001 to operate properly. This is especially important for proper operation of the fiber oscillator. DO NOT attempt to optimize fiber laser operation unless the temperature stabilizer loop has been on for at least 24 hours.**

5.2 Diagnostics

In case the SErF is not operating properly, the system contains several diagnostic components that allow you to troubleshoot the system and provide the engineers at Clark-MXR with the information necessary to diagnose your problem.

As shown in Figure 5-2 of the rear view of the CPA-2001, there are two monitoring ports.

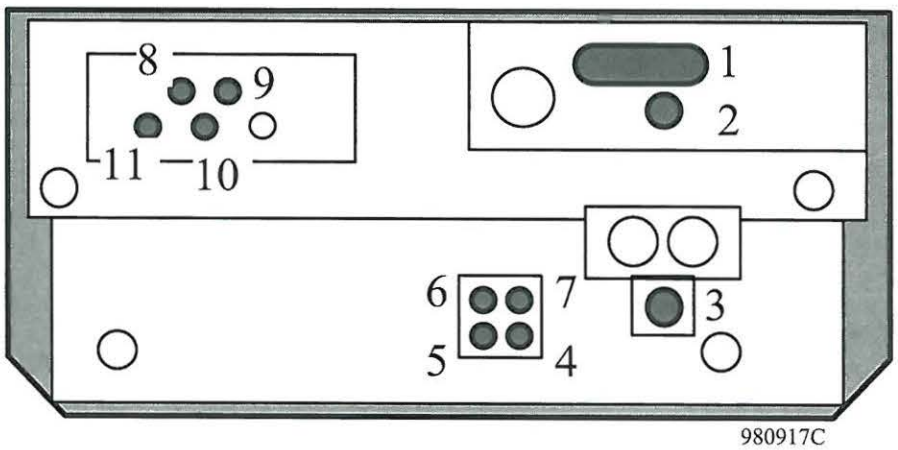


Figure 5-2
CPA-2001 rear panel

- Port 7 (mode-locking monitor) is a photodiode signal that allows the user to monitor the mode-locking behavior of the fiber laser when connected to a scope with a 50-Ohm input. Use a 10ns/division scale on the scope.

- Port 4 (PPLN monitor) allows for the measurement of the PPLN temperature. The PPLN crystal is kept in a small oven heated to approximately 80 degrees Celsius to avoid optical damage to the crystal. The frequency doubling efficiency is optimal at this temperature. At the standard operating temperature, Port 4 will be very stable at a value between 1.3 and 1.8 KOhms. If the oven is not working at all, this port will have a resistance of approximately 10 kilo-Ohms.

The board with the control electronics for the laser diode also contains some system diagnostics. This board is mounted on the side of the CPA-2001 casting and is visible through a window in the access hatch shown in Figure 5-3. The board layout is shown in Figure 5-4. The digital display to the right is a readout of the laser diode current. The digital display to the left is a readout of the output power of the laser diode. The board runs in a constant power mode of operation, and the power is normally set around 150 mW.

Figure 5-3
Location of the fiber laser control electronics board.

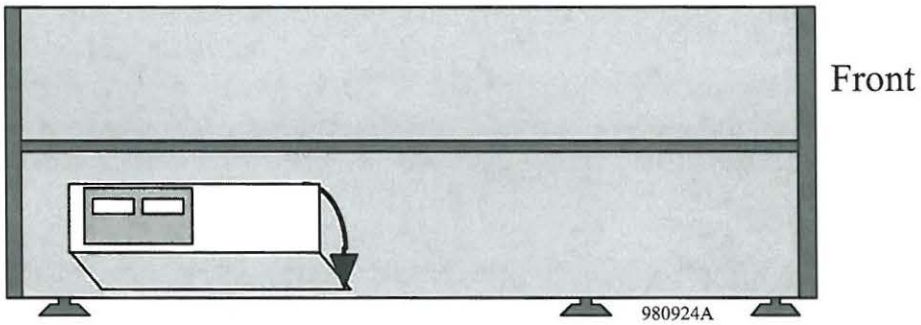
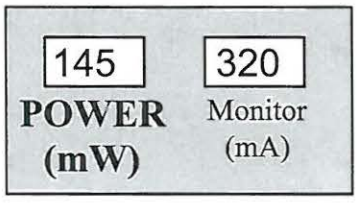


Figure 5-4
CPA-2001 fiber laser control electronics board



There are also two green labeled LEDs at the upper left of the board. During normal operation, both of these diodes are lit. If LED 1 is off, it indicates the temperature stabilization of the laser diode is not working correctly. If LED 2 is off, it indicates the PPLN oven temperature is too low. Either of these fault conditions will turn the laser diode off, resulting in a power reading of 0 mW.

- **There are a number of potentiometers on the diode control board. DO NOT touch these. They have been adjusted for the correct operation of the laser diode and readjusting them can damage the laser diode.**

- **DO NOT touch exposed fiber!**

The fiber oscillator should be left running at all times. Make sure the water temperature stabilization loop is left on at all times as well. If it is necessary to turn off the fiber oscillator, it is sufficient to flip the main power toggle switch on the back of the ORC power supply to the off position.

- **Do not turn off the water circulator used for thermal stabilization of the CPA-2001. Also check the water level on a regular basis.**

5.3 Pulse Stretcher (bottom level of CPA-2001)

There are no user-serviceable parts in the bottom level of the CPA-2001 laser system including the parts in the Pulse Stretcher compartment.

5.4 ORC-1000 Nd:YAG Pump Laser Operation

The section to follow lists the ORC features unique to the CPA-2001 laser system.

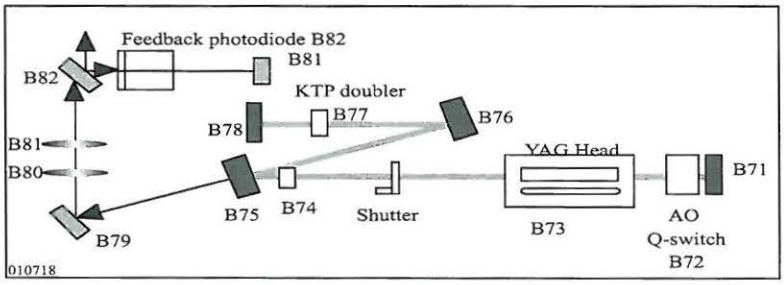


Figure 5-5 Schematic view of ORC-1000 laser head

5.4.1 ORC-1000 Features Unique to CPA-2001 System

- **Power must be maintained to the ORC power supply at all times.**

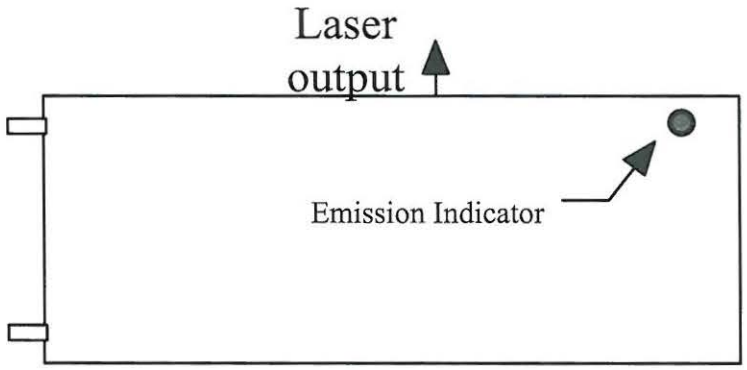
1. *Main Shutter*: The main shutter switch on the ORC power supply unit controls two mechanical shutters in the CPA-2001 system: the ORC intracavity shutter and an injection shutter in the pulse stretcher compartment in the bottom level of the CPA-2001 laser head. With this main shutter switch off, there will be no laser radiation coming out of the CPA-2001.

   A. The intracavity ORC shutter controls the ORC (YAG). When this shutter is closed, there is no green output and the feedback loop will be disabled.

   B. The injection shutter controls the seeding into the regen. When it is closed, the regen will operate in a free-running nanosecond regime.

2. *Emission Indicator*: The location of the emission indicator in the CPA-2001 is shown in Figure 5-6.

Figure 5-6
Emission indicator position in CPA-2001



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When the key on the front panel of the ORC power supply is turned on this indicator should come on. If it doesn't, re-check all of the system interlocks.

3. *Power Stabilization System*: The ORC in the CPA-2001 system incorporates a feedback-loop power stabilization circuit to provide a long-term pump power stability. This stabilization circuit can be activated and deactivated using a switch provided on the front panel of the ORC power supply (as shown in Figure 5-7).

The feedback-loop circuit includes a photodiode monitor in the ORC laser head that monitors the 532nm power fluctuation. The location of this photodiode is shown in Figure 5-5.

Figure 5-7
Front panel of ORC-1000 power supply showing feedback active switch location

The procedure for turning on and off the active power stabilization system is as follows:

a. Place a power meter head after the ORC laser head just inside the regen cavity to measure the average power.

b. Turn on the ORC power supply and the lamp and let them warm up for 5 minutes.

c. Open the mechanical shutters using the shutter switch on the front panel of the ORC power supply.

d. Measure the 532nm power output from the ORC laser head using a power meter and set to your desired power level.

e. Activate the feedback-loop circuitry by turning on the feedback active switch on the front panel of ORC power supply. When the switch is turned on, the arc lamp current will go to the minimum level (below 18 A) and will increase slowly to the current that was set in the last feedback turn-on.

f. Measure again the 532nm power output.

g. Adjust the 532nm power to the desired level by adjusting the pot shown in Figure 5-8 above. The number shown by the LED indicator is an arbitrary number.

- **Note this number as a reference to the 532nm power output level setting.**

h. To turn off the active power stabilization circuit, the feedback switch on the ORC power supply front panel is turned off. The lamp current can now be manually adjusted using the standard knob provided for this purpose on the front panel.

- **Feedback must be reset every time the repetition rate or the lamp is changed.**

5.5 Ti:Sapphire Amplifier

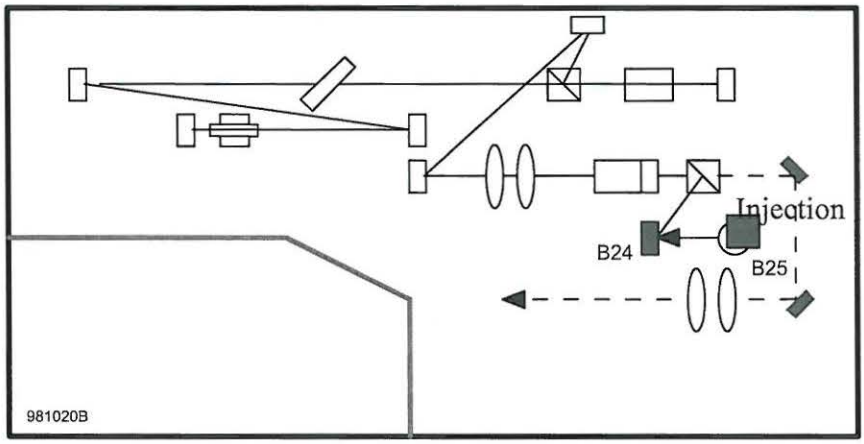


Figure 5-8 Schematic view of the regenerative amplifier

The regenerative amplifier was factory aligned. It should not require any realignment after installation with the following exceptions:

- Optimization of the timing
- Optimization of the seed injection

See Chapter 6 for more information.

5.5.1 Safety

- **Be careful! The output of the Regenerative Amplifier is extremely powerful. However, the near IR wavelength emitted by this unit is almost beyond the range of human vision. What appears as a low intensity red beam is in fact a very high intensity beam that can cause permanent loss of vision.**

5.5.2 Support Equipment

The following user-provided equipment is necessary to monitor the operation of the Regenerative Amplifier:

- Power meter (reading up to 10 Watts)
- Oscilloscope [bandwidth ≥ 350 MHz (analog)]
- Infrared viewer

Included with the Clark-MXR Regenerative Amplifier package is a fast photodiode.

5.6 Pockels Cell Driver

5.6.1 Overview

The PC Driver controls all synchronization including the seed pulse in the regen amplifier and its cavity dumping after amplification.

The model Pockels cell control system consists of three subsystems:

The DT-505 includes the various power supplies required to power the system. The synchronization circuitry and timer board are also found in the DT-505.

The high-voltage switching unit, model HVS-505. The HVS-505 is attached to the side of the CPA-2001.

A Pockels cell assembly, found in the CPA-2001 regenerative amplifier.

- **Do not change cable lengths after installation. It will strongly influence performance.**

5.6.2 DT-505 Sub-System Description

Control Unit Function

The function of the DT-505 is to control the level and the sequence of the voltages applied to the Pockels cell assembly.

The electronic circuitry is divided between the control unit and the HVS-505. However, all operator-adjustable controls are located on the DT-505's front panel.

Timing Board

The timing board contains the countdown circuitry that generates the user-selected repetition rate, as well as several digital delay generators and their associated synchronized outputs. The high voltage pulse sequence is fully controlled by the timing board.

Figure 5-10 shows a *flowchart* of the timing board logic.

Repetition Rate

The fundamental input is provided by a fast photodiode monitoring the fiber laser installed inside the bottom level of the CPA-2001. (The repetition rate of this source must be in the 25 to 40 MHz range.) The input level should be in the 50 to 200 mV range (50 Ω load).

The photodiode signal is filtered and amplified. This filtered signal (sine wave) forms the basic clock rate. (A fraction of this signal is available on the back panel of the control unit.)

This RF signal is divided by 2, then transformed into a TTL compatible signal. This TTL-level signal is available at the back of the control unit.

The clock rate is internally divided by 1000, then divided again by a user selected integer (selected from the front panel). The end signal repetition rate is available (in a TTL format) at the three outputs labeled *Audio 1*, *Audio 2* and *Audio 3*.

Digital Delay Generators

The DT-505 incorporates three independent digital delay generators and various auxiliary synchronized outputs. Delay 1 and Delay 2 control respectively the first high voltage step and the second high voltage step.
A synchronized TTL level output is provided with these two delay generators.

Delay 3 is not tied to the high voltage circuitry. It is provided as a convenience to the user and is available for any additional synchronization needs.

"Zero" delay provides early output to which the delays are synchronized. Zero delay is normally used to trigger the pump laser for the regenerative amplifier.

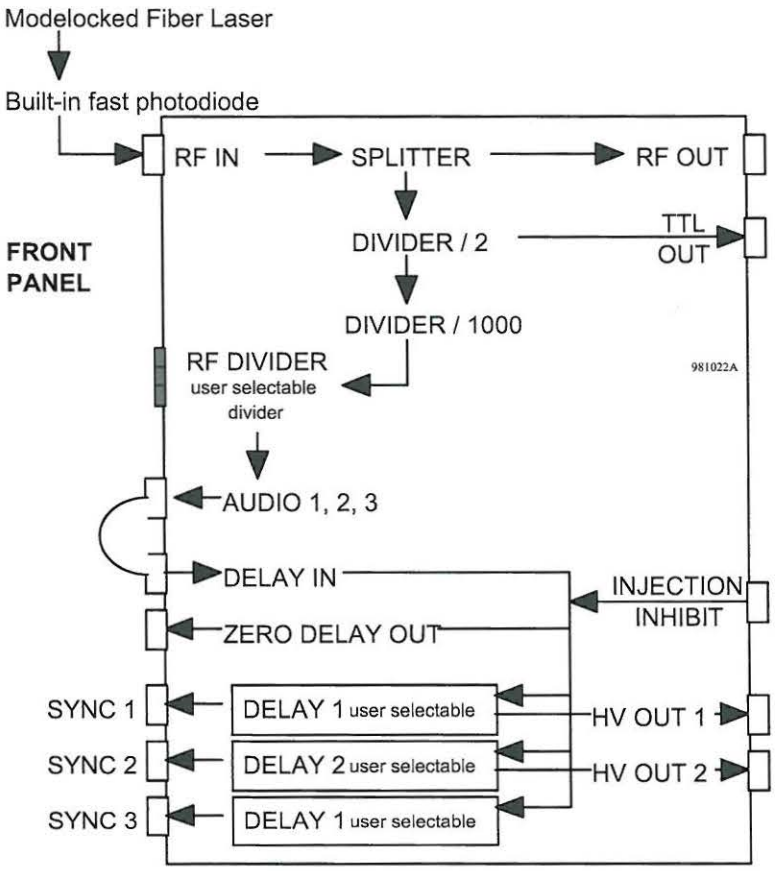
The four delay generators share a common input (labeled *Delay In*).

For standard operation, this input *Delay In* port is tied, via a short coaxial cable, to one of the three *Audio Out* ports.

The user can select each delay through the control unit front panel (switches labeled *Delay*). The desirable delay is selected by affixing a first integer (three digits) and a second integer (two digits). The first integer selects the number of clock cycles that will form the digital portion of the delay. The second integer corresponds to a small analog delay. Each unit corresponds to approximately half a nanosecond. The

analog delay counters are Hexadecimal based. The two portions (digital + analog) form the full delay.

Figure 5-9
Timing Board – Logic Flow Chart



The high voltage is adjustable from the front panel of the DT-505. Two test points, located on the back panel of the DT-505, provide a means of measuring the high-voltage. (The voltage as measured at these two test points corresponds to 1/1000 of the high-voltage provided by the HV power supply.)

5.7 HVS-505

The function of the High-Voltage Switching unit, model HVS-505, is to switch on and off the voltage applied to the Pockels cell. The HVS-505 is composed of two identical units. Unit A is controlled by the DT-505 through *Delay 1* and *HV 1.* Unit B is controlled by the control unit through *Delay 2* and *HV 2.* Unit A is attached to one electrode of the Pockels cell and Unit B is attached to the other electrode. The voltage

difference between the two electrodes determines the amount of phase retardation (see Figure 5-11).
Note that there is a second *window* approximately 20 microseconds after the first one. This second window has no impact on the performance of the system. The rise time and fall time are typically 8 ns.

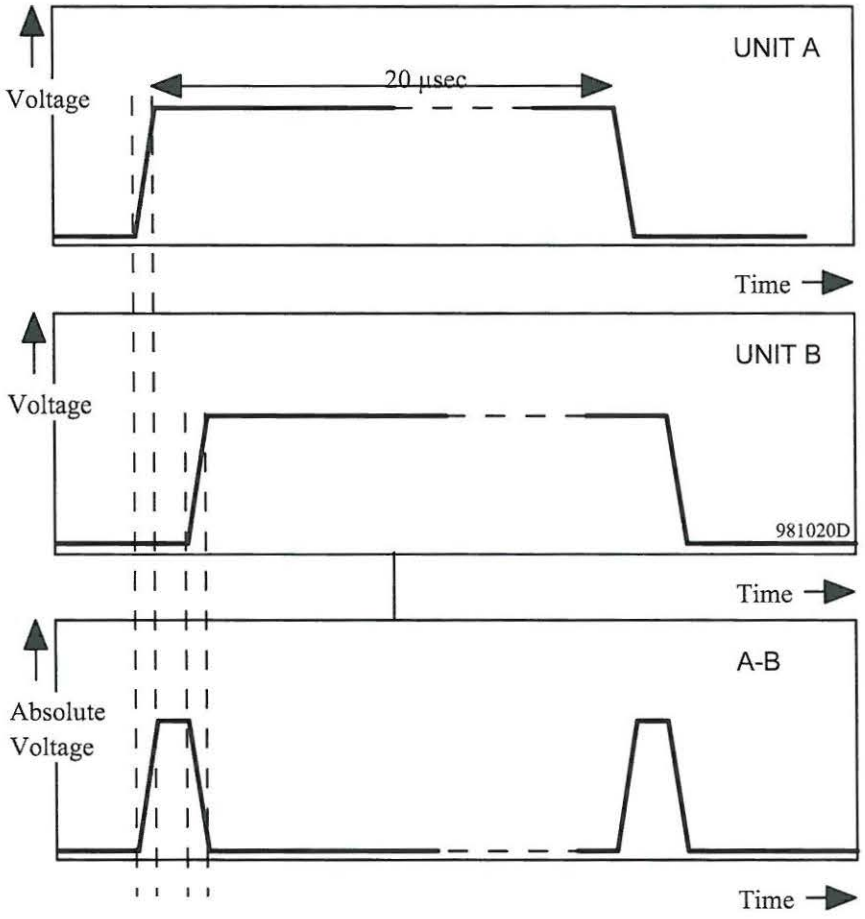


Figure 5-10 Voltage sequence at the level of the Pockels cell.

There are no user serviceable components in the HVS-505. For thermal management reasons, the units A and B are potted with a thermally conducting compound in the factory and cannot be field-serviced.

5.8 Pockels Cell

The Pockels Cell Assembly is formed of the Pockels cell proper (*that is*, an electro-optic crystal enclosed in an optical cell) and a multi-axis mount designed to provide all of the degrees of freedom necessary for the alignment of the cell.

5.9 Operation

5.9.1 Control Unit (DT-505) Front Panel

All of the user-adjustable controls are located on the front panel of the DT-505.

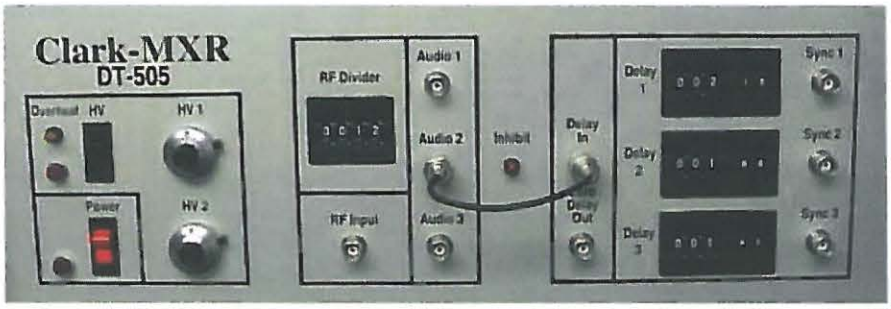


Figure 5-11 Front panel of the DT-505

The front panel is divided into three main sections (see *Figure 5-11*). The left-hand section contains the various power supply functions. The middle section contains the adjustments for setting the repetition rate. Finally, the right-hand section contains the various delay generators.

The "power" switch controls the power to the timing board. It must be **on** at all times, except during servicing.

The "HV" switch controls the high voltage power supply. It must be set in the *on* position during operation of the Pockels cell. This switch should be set in the *off* position if you are not planning on using the Pockels cell, but need to use the timer.

- **Do not turn on this switch without first connecting the DT-505 with the HVS-505 and the Pockels Cell using the appropriate sets of cables.**

HV1 ADJ and HV2 ADJ

These rotary dials are used to adjust the voltage level produced by the high voltage supply. The numeric indicators provide a relative reference. It does not provide an absolute calibration of the high voltage. The voltages were factory adjusted and should not need readjustment.

The HVS-505 dissipates large amounts of heat when operating at high repetition rates. Several thermal sensors imbedded in the HVS-505 will shut down the DT-505 if factory preset values are exceeded. The *overheat* light (on the front panel of the DT-505) is lit when this undesirable condition occurs.

If the *overheat* light indicates such a condition, then shut off the control unit (HV and POWER). Let the HVS-505 cool to room temperature, and check the laser cooling system for proper operation. If failure persists, contact customer service.

- **Note that the HVS-505 is NOT designed to operate above 5 kHz, even though the logic board can operate at higher repetition rates.**

5.9.2 Control Unit (DT-505) Back Panel

Figure 5-12 Back panel of the DT-505

VAC Select
Fused power connection to line voltage. Check that the proper input voltage is selected.

RF Out
This BNC connector provides a 750mV *sine wave* synchronized with the *RF In* photodiode signal. It can be used for synchronization with other control units.

TTL Out
This BNC connector provides an approximate 2.5V TTL-level sign synchronized with the *RF In* photodiode signal. The TTL frequency is 1/2 of the fundamental *RF In* frequency.

HV/1-Trigger/1-Bus
These three connectors should be connected to HVS-505 unit A (see section 5.7).

- **CAUTION! Lethal voltages are present at the HV connector when the HV switch (front panel) is ON.**

HV/2-Trigger/2-Bus
These three connectors should be connected to HVS-505 unit B (see section 5.7).

TP1
Test point 1 for the high voltage associated with side 1 (SYNC 1). The voltage corresponds to 1/1000 of the voltage on HV side 1.

TP2
Test point 2 for high voltage associated with side 2 (SYNC 2). The voltage corresponds to 1/1000 of the voltage on HV side 2.

Inhibit
Normally disabled when jumper cable is plugged into back of unit.

5.10 Connections

There should be one umbilical cord incorporating two sets of three cables to connect to the back panel of the DT-505.

- CAUTION! The two sets of three cables should be connected or disconnected between the DT-505 and the HVS-505 only after turning OFF the DT-505 (Power and HV). Lethal voltages are present at the HV connectors when the HV switch (front panel) is on.

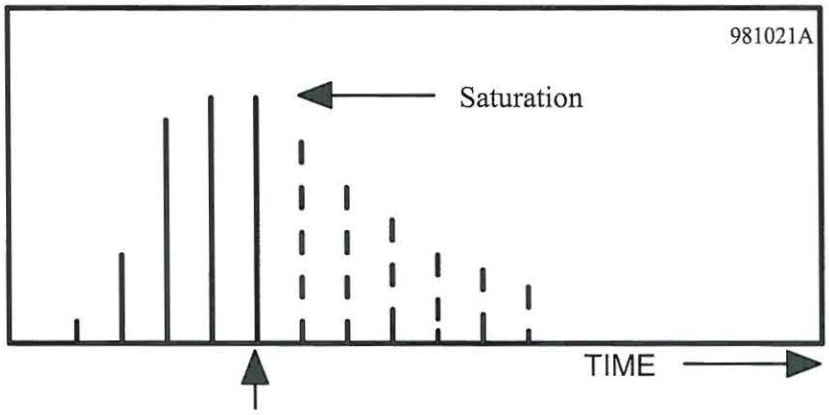
6 Optimizing the Regenerative Amplifier

6.1 Seed Pulse Alignment Optimization

Injection is controlled by mirrors
24 and B25 (see Figure 5-9), which control the seed beam from the CPA-2001 stretcher. Mirrors B24 and B25 are sometimes called the injection mirrors. The injection mirrors
are used to align the seed beam to the amplifier output making them colinear. This process is done in the factory. Occasional adjustments to B25 should be done by the user to keep the injection well aligned.

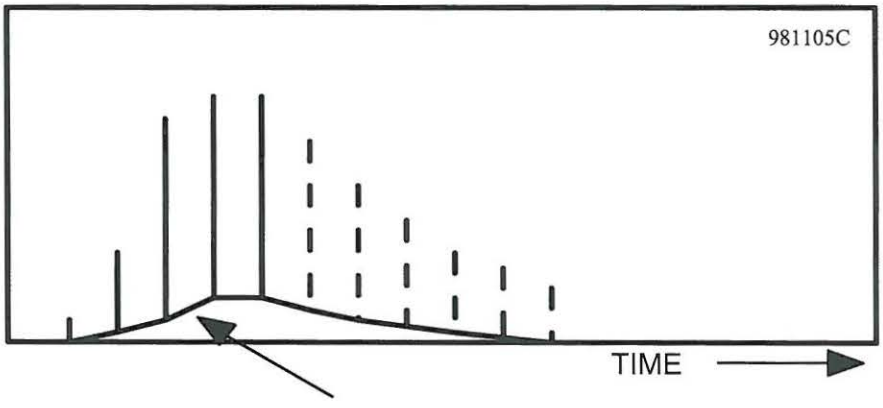
This is done by gently adjusting the horizontal and vertical control of B25 alternatively while watching the rising pulse train (port 8, Figure 3-8). The operator should try to maximize the early, non-saturated pulses in the pulse train.

Figure 6-1 Amplified pulse train (typical)



- **Do not exchange cables. Cable length does affect timing.**

Figure 6-2 Poor injection alignment showing background amplified stimulated emission (ASE)



6.2 Injection Timing Optimization

The injection of the laser is monitored using the photodiode pre-installed in the CPA-2001. The BNC connector is on the CPA-2001 casing near the water inlet port 8 (Figure 3-7). It should be connected to a fast, analog oscilloscope (350 MHz or better) using a 50Ω input.

1. Injection timing is controlled using Delay 1 on the DT-505. It is set at installation for peak power and should not be adjusted by the user.

2. Delay 2 controls the output timing of the amplifier. It is set to switch out the pulse after it has reached gain saturation. This is determined by a sharp reduction in peak-to-peak fluctuation as the rising pulse train reaches peak amplitude (Figure 6-1). Delay 2 is also set at installation.

7 Pulse Compressor

7.1 Safety

- **Be careful! Remember that the IR wavelengths emitted by the Ti:Sapphire oscillator and greatly amplified by the regenerative amplifier are *almost* beyond the range of human vision. What appears as a low intensity red beam is in fact a very high intensity beam which can cause permanent loss of vision! Be aware of the beam propagation paths within and external to the modules.**

7.2 Pulse Compressor Alignment

An internal layout of the compressor identifying the various components is presented in Figure 7-1.

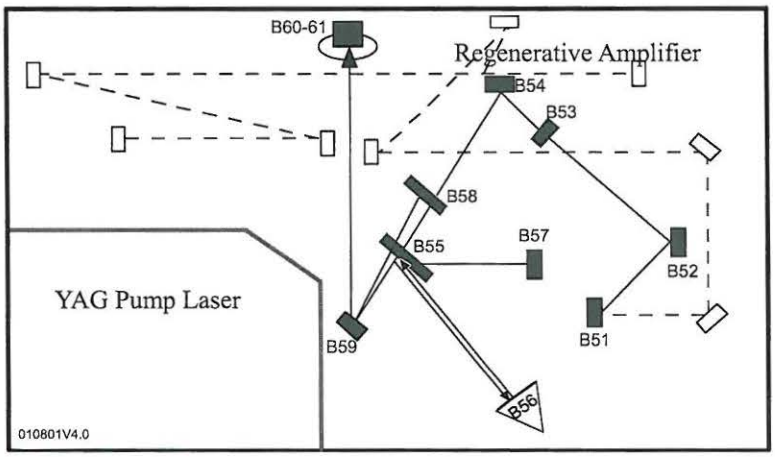


Figure 7-1 Schematic view of compressor

The compressor was aligned at the factory. It should not require readjustment after initial installation, except for the fine tuning of the final pulse duration.

7.3 Compression Optimization

The compression optimization is achieved by adjusting the distance between the grating, B55, and the prism assembly, B56. These optimizations require the use of an autocorrelator such as the Clark-MXR Model AC-150.

1. Measure the autocorrelation pulse width.

2. Using the external remote control, increase or decrease the distance between the grating and Prism, and monitor the pulse duration. See Figure 7-1. Optimize for best pulse duration.

8 Trouble-shooting

The CPA-2001 system is designed to meet all specifications provided it is operated as stated in this manual. Should a problem occur, follow the sample procedures listed below. Should you not be able to eliminate the problem, contact Clark-MXR (in the U.S.) or your local distributor (overseas).
To speed support, please have the following information ready:

- Model
- Serial #

Problem 1. Oscillator is not mode locked.

Solution

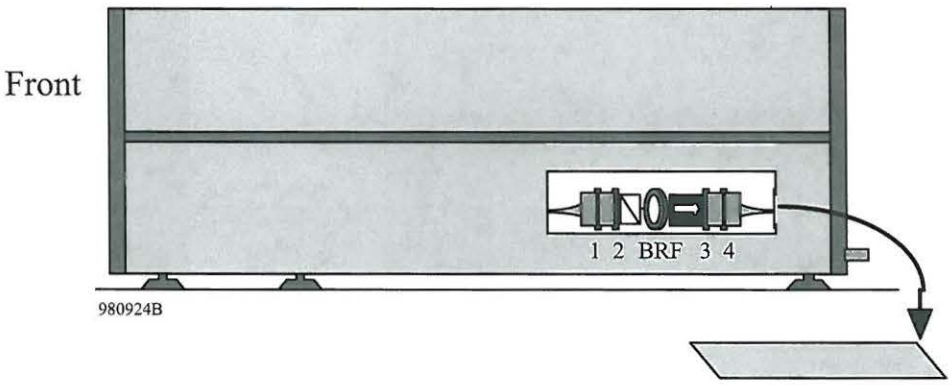
Infrequently, the free-space optics in the SErF may need adjusting. This is required ONLY if the fiber laser does not mode-lock, or the mode locking is unstable, and ALL other operating conditions are normal. Specifically, before attempting to adjust any of the free-space optics, make sure:

1. Verify the oscillator is really **not** mode locked. Connect Port 7 (Figure 3-8) to 50 Ω oscilloscope (10-50 mV vertical scale, 1ms horizontal scale). Check that you can observe "noise" but no mode locking. When mode locked properly, the top of the trace should be flat and show no sign of Q-switching.
2. The water circulator is set at the correct temperature and has been on for at least 24 hours.
3. The room temperature is within two degrees of the standard room temperature.
4. The laser diode is operating correctly, reading >145 mW.

If the above conditions are met, and the fiber laser is not mode locked correctly, the free-space optics may be adjusted. These optics tune the polarization state of the laser, allowing the compensation of any birefringence change in the fiber. Access to these optics is provided through a hatch in the side of the CPA-2001 casting as shown in Figure 8.1. The optical elements from left to right are:

Waveplates 1 & 2
A polarizer
A birefringent tuner
A faraday isolator (the cylindrical tube in the cubic mount)
Waveplates 3 & 4.

Figure 8-1 SErF free space optics hatch

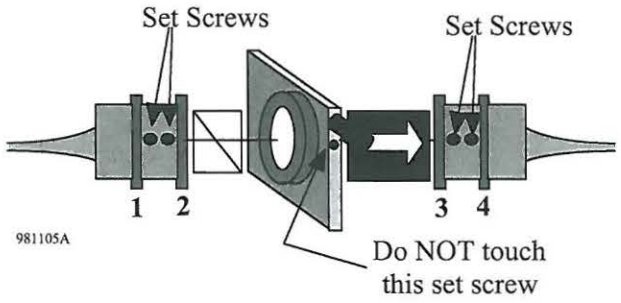


Before beginning, make sure the waveplates are marked so that you can get them back to their original positions.

The first waveplate to touch is waveplate 4. Loosen the set-screw shown in Figure 8-2 (some units may not have set screws) for this thumbwheel.

Adjust the waveplate to get the mode locking most stable (typically the laser will mode lock over about 5 degrees of rotation). If you can get it so the mode locking train looks flat on top (looking at the output of the mode locking monitor port on an oscilloscope), the laser is working well.

Figure 8-2 Location of set-screws on waveplates



If you cannot get things running well with just tweaking waveplate 4, then waveplate 3 will need adjusting as well. This is a little bit trickier because by adjusting two waveplates, you can potentially mode-lock the laser in a completely different mode locking regime. This potentially causes the output pulse to have different dispersion, and it will not be effectively compressed by the prism compressor. The best way to avoid this is to watch the scope. If, while you tune the waveplates, there is a sudden jump in the level of the trace on the scope, you have probably switched regimes.

The best method for tweaking the two waveplates is as follows: tweak waveplate 3 a tiny bit–just enough to see some effect on the scope trace. Then, adjust waveplate 4 for best mode locking as above. If things look better than before, good. Try another small tweak on 3 and then readjust 4 again. If things seem worse, try tweaking 3 in the other direction. Stick to small adjustments of 3 at a time. If you move 3 a lot at once and then tweak 4 to get mode locking, you risk mode locking in a different regime.

Finally, if things are close and you wish to optimize the system just a little bit more, you can try adjusting the birefringent filter. Adjusting this can often make the mode locking train a little smoother. Use adjustments of about 1/8th rotation of the BRF adjustment knob (see Figure 8-2). While the system is mode locked, adjust one increment in a given direction. If the mode locking is better here, good. If not, try adjusting in the other direction.

Most likely, this procedure will work for you, and you will get satisfactory mode locking. If not, all waveplates might have to be completely readjusted. There is no good, set procedure for this. In addition, the pulse compression may have to be redone if the mode locking regime is changed. Therefore, please contact us if you cannot get satisfactory performance with adjusting two wave-plates.

Problem 2. Low output energy.

Solution

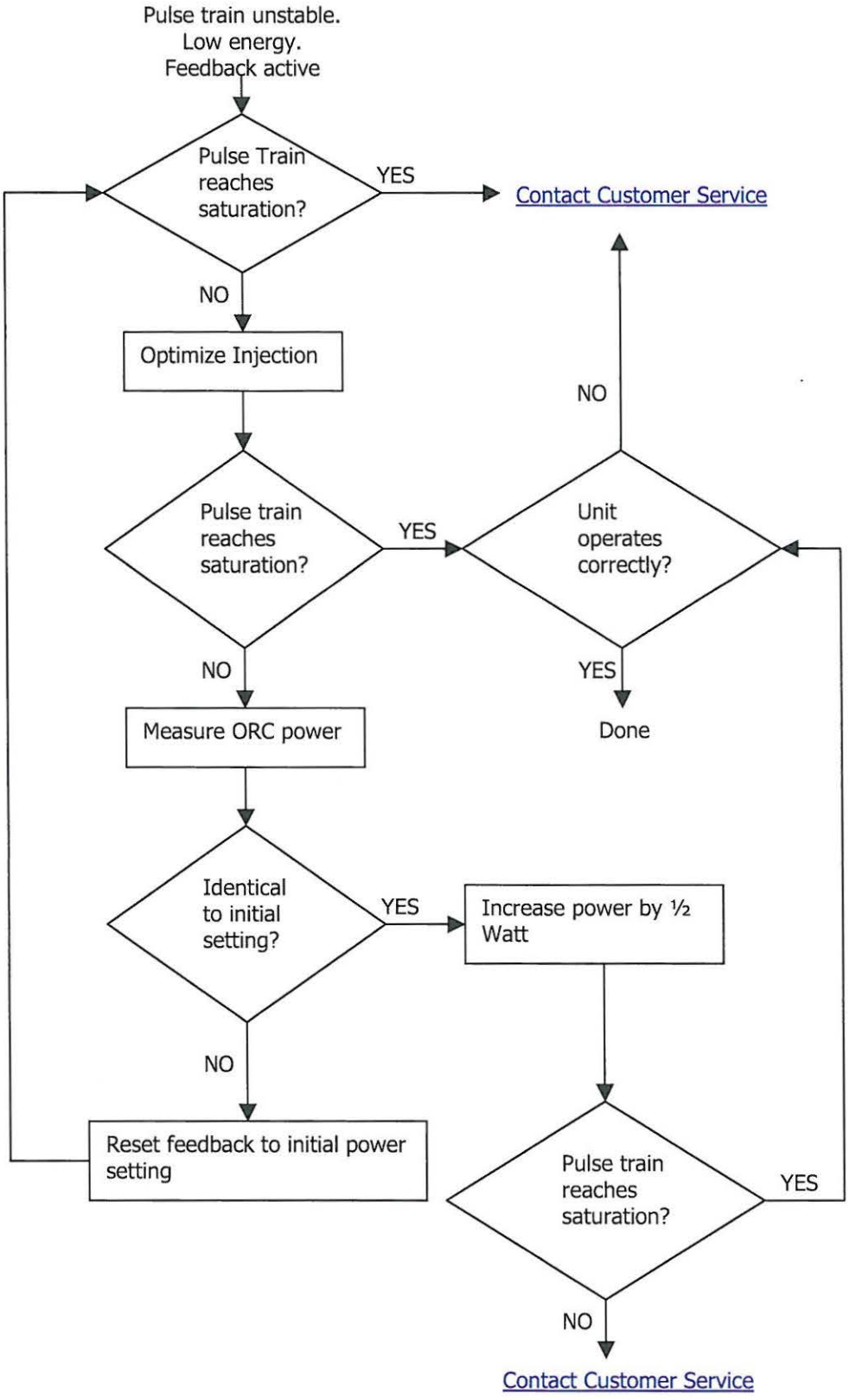
1. Check water flow and temperature of chiller water.
2. Check power meter scaling.
3. Check repetition rate.
4. Check that oscillator is mode locking properly, and that ORC is Q-switching correctly.
5. Using the built-in photodiode (port 8, Figure 3-8), check the injection rise-time, and optimize the injection as per section 6.1.

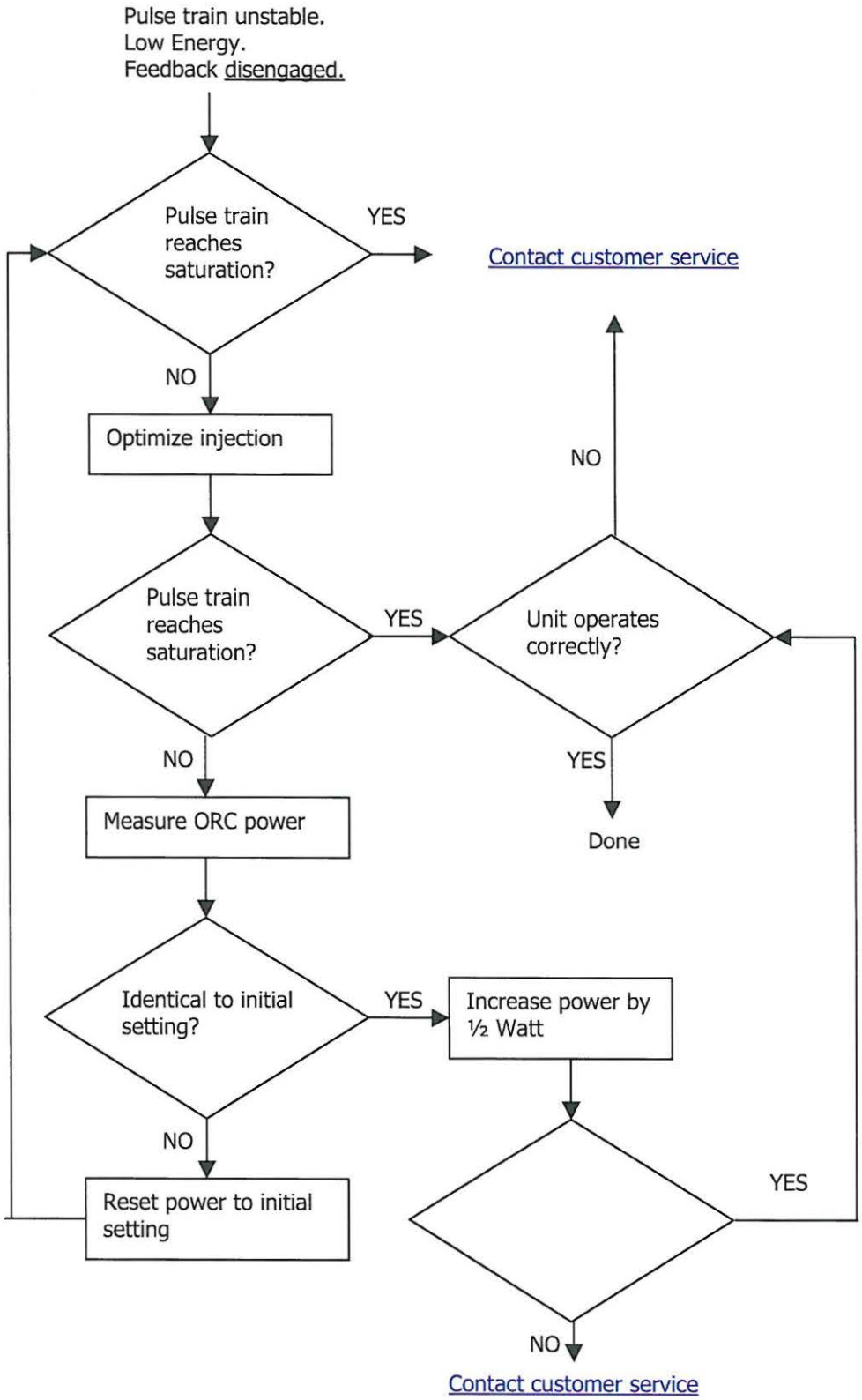
Problem 3. Amplitude noise on output — should be 2% RMS or less.

Solution

1. Check that the oscillator is mode locking properly.
2. Check DT-505 operation (correct RF input power, switch out delays, injection timing).

Trouble-shooting Flow Charts Related to Problems 2 and 3:





Problem 4. Temporal jitter.

Solution

1. Check that the oscillator is mode locking properly.
2. Check Q-switch repetition rate.
3. Check water flow and temperature of chilled water.
4. Check DT-505 RF input voltage.
5. Have cables been changed or added? If yes, restore original cables.
6. Contact customer service.

Problem 5. Pulse width is too broad.

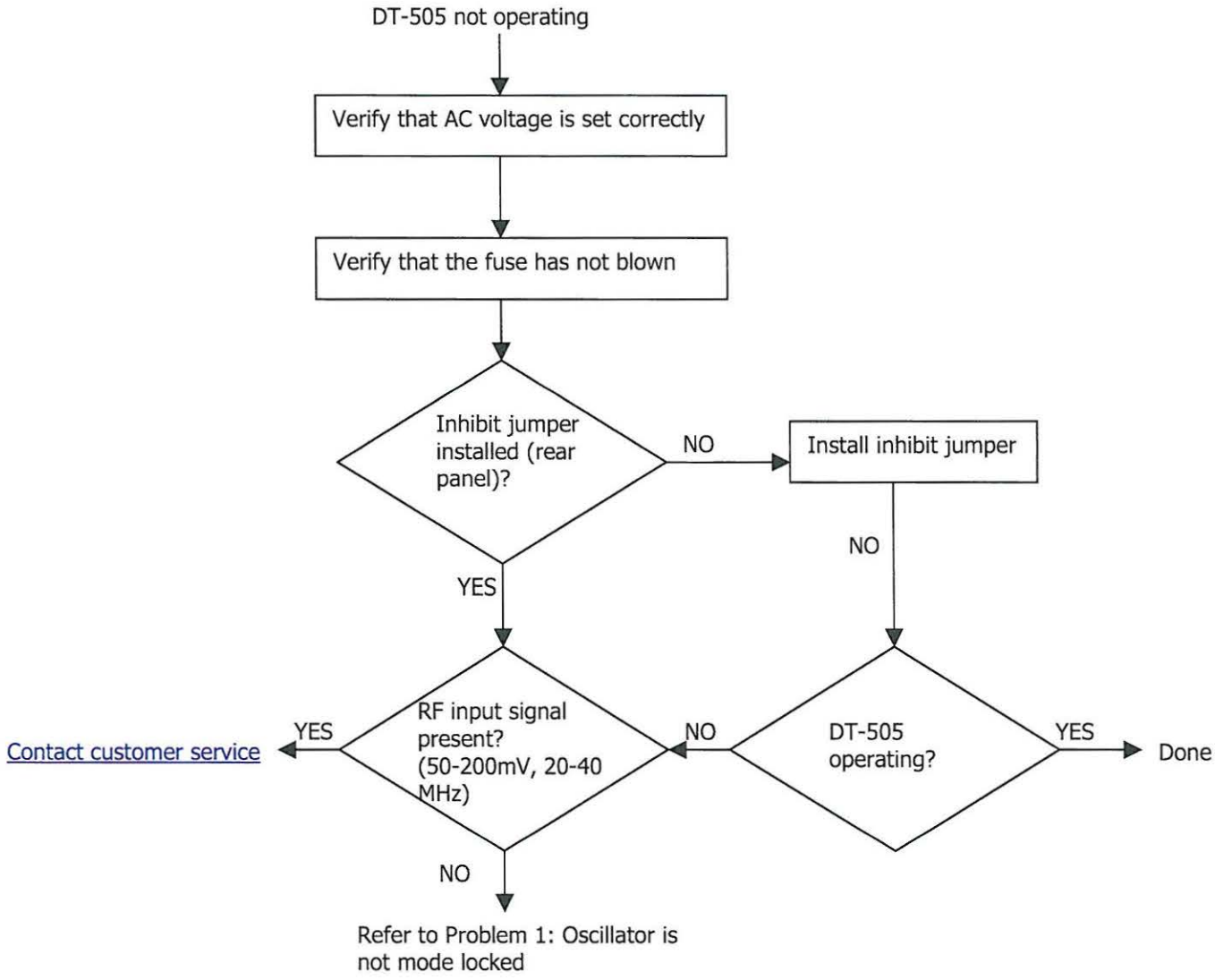
Solution

1. Check the autocorrelator calibration and alignment.
2. Adjust the length of the compressor using the translation stage adjustment.

Problem 6. DT-505 is not operating.

Solution

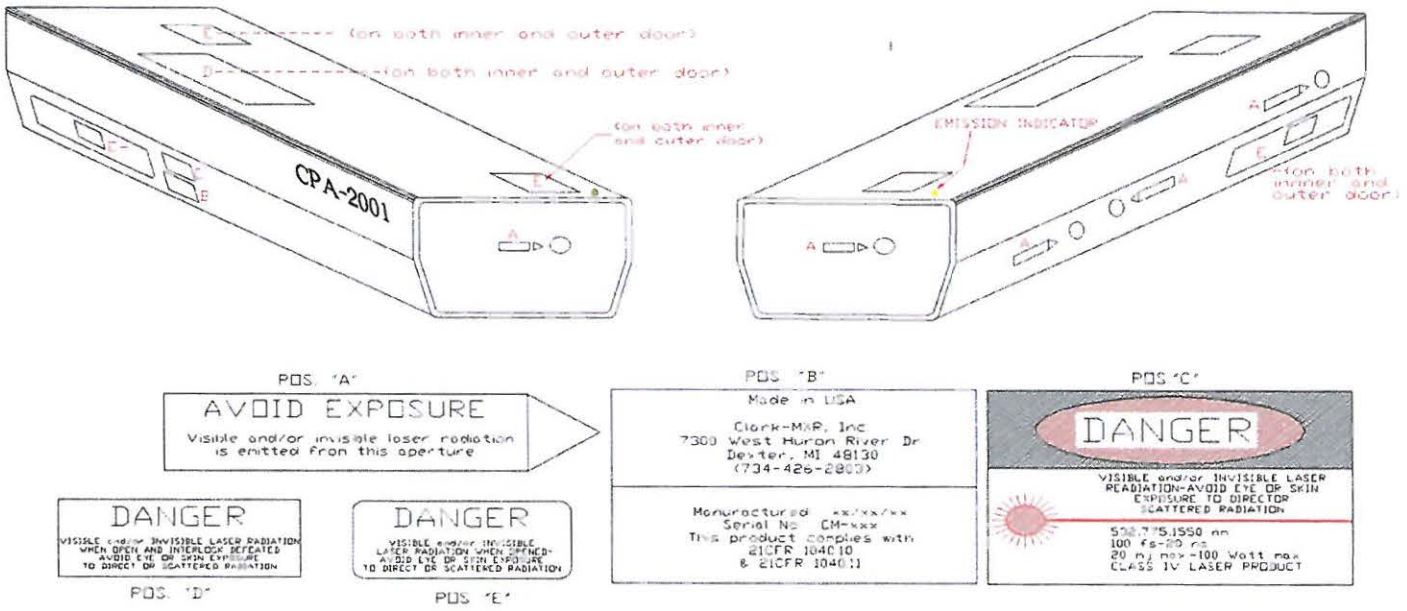
1. Check that the oscillator is mode locking properly.
2. See flow chart on following page.



9 CPA-2001, Location of Labels

In accordance with CDRH regulations, the location of the various safety labels that should be affixed to your CPA-2001, are shown in Figure 9-1. The function of the labels is to provide the user with information on the wavelength and power emitted and to warn the user against exposure to laser radiation. Do not remove these labels.

Please refer to Chapter 1 for detailed Eye Safety information.



10 Maintenance

10.1 Changing the ORC-1000 Lamp and De-ionizing Filter

- **Whenever the arc lamp is replaced, the YAG rod mounting/seal assemblies should be examined for signs of erosion induced by optical radiation from the arc lamp.**

1. De-energize the circuit breaker, then remove the main power plug from the wall outlet.

2. Remove the top cover of the ORC laser head by removing the four screws securing it in place.

3. Remove the NYLON top plate and white protective blocks from the lamp housing, then measure across both terminals for zero (0) volts.

- **It takes several minutes for the lamp voltage to bleed off the filter capacitors.**

4. Put on protective goggles to guard against possible lamp explosion.

- **WARNING! Because of potential danger from an exploding lamp, protective goggles must be worn before removing the top from the lamp housing.**

5. Remove the eight socket cap screws from the lamp housing. Lift the top of the lamp housing slightly (do not completely remove the top) and let the housing sit momentarily to enable any excess water to drain out.

6. Remove the top cover. The lamp is attached to the back of the top cover.

7. Remove two button-head screws from each of the lamp mount connectors.

8. Carefully note the orientation of the anode and cathode of the old lamp. The lamp base coded red is the anode and should be

connected to the "+" power station lead (The lamp anode tip is rounded while the cathode tip is pointed).

9. Slide the lamp out either end.

- **Do not touch the envelope of the new lamp with your bare fingers. If this happens, clean the lamp with acetone or methanol before installing it (This prevents skin oil from etching the lamp).**

10. Check the orientation of the anode and cathode of the new lamp in the holders. Attach lamp mount connectors on each end. Make sure the lamp is centered within the holders and both lamp bases should be equally inserted into the spring end and connectors. Screw two button-head screws into the mounts.

11. Replace the white protective blocks, the nylon protective top, and the securing screws (Do NOT over-tighten the eight securing screws).

12. Replace the deionizing filter on the back of the power supply.

13. "Defeat" the system interlock by pulling it into the "up" position.

14. Turn the pump on and verify that there are no water leaks. Bring the system up to normal operation. Realignment should not be necessary.

15. Shut down the system and push the interlock defeat switch to the down position. Replace and secure the cover.

10.2 Changing O-ring Seal

- **Rod seals should be changed every 1500 hours. See Appendix A for rod seal replacement kits.**

10.2.1 Cleaning Procedure

1. Completely remove all excess dirt, dust or other contaminates in the rod by flushing it with methanol.

2. Apply the drip and drag method to the faces of the rod with lens tissue and methanol.

3. Inspect the surface. If not clean, repeat steps 1 and 2.

4. Swirl clear O-rings in methanol for two (2) minutes, air dry for 20 minutes.

10.2.2 Assembly of the YAG Frame and Installation

1. Finger coats should be worn at all times when the YAG rod is being handled.
2. Cleaning the YAG rod should follow the above mentioned procedures.
3. Inspect YAG rod.
4. If necessary, clean rod ends only with methanol. Inspect coated ends for scratches, digs, flaws and damage. Use a 8-10X microscope if possible.
5. Using calipers, measure 0.10 inch from the end of the rod, being very careful not to touch the rod end with the caliper blades. Mark lightly with a pencil on the side of the rod. Repeat at other end.
6. Slip clear O-ring down one end of the rod shaft to the pencil mark. Be careful not to touch the rod surface.
7. Slip female rod holder carefully over the other end of the rod with threaded hole facing the O-ring at the opposite end.
8. Using compressed nitrogen or argon at approximately 30psi, blow off the O-ring and inside of cap, being careful to aim the gas stream at an angle, towards the O-ring and not at the rod surface.
9. Place second female holder on rod from the other end, threads facing outward. Mount the second O-ring.
10. Repeat step 8.
11. Re-inspect the rod ends. Clean with methanol only if necessary.
12. Slide the female rod holders onto each end of the rod so that the pencil marks are visible. Be careful that the O-rings are not pushed off the ends.
13. Screw the four 4-40x0.25 screws into the YAG frame and female rod holders. Do not completely tighten.
14. Screw the male YAG rod holders into the female rod holders finger-tight and allow them to center themselves in the frame.
15. Tighten the 4-40x0.25 screws.

16. Screw two 4-40 nylon tip set screws into the YAG frame.
17. Make a mark with a felt-tipped black pen on the male rod holder nearest to the serial number to mark the "in" end. Note this should be the shutter side of the rod.
18. Do a final visual check on the rod for particulate matter on the ends before placing it back into the rod housing.
19. Use the four 4-40x0.625 cap screws to secure the rod frame to the rod housing.

To disassemble the rod, please reverse the steps.

10.3 Temperature Stabilization Loop

- **Low water level in the chiller may result in freezing of the reservoir.**

1. Add algicide according to manufacturer's recommendation as noted on the algicide bottle.
2. Add distilled or deionized water as needed.

11 References

11.1 General References

–A.E. Siegman, Lasers, New York: University Science Books (1986)

–W. Koechner, Solid-State Laser Engineering 4ed., Berlin: Springer Verlag (1996)

11.2 Erbium Fiber Oscillators

–K.R. Tamura, Additive Pulse Mode locking Erbium Doped Fiber Lasers, Massachussetts: MIT (1994)

11.3 Chirped Pulse Amplification (CPA)

–P. Maine, D. Strickland, P. Bado, M. Pesset, G. Mourou, IEEE J. Quantum Electronics, Vol. 24, No. 2, 398 (1988)

–P. Bado, M. Bouvier, S. Coe, Optics Letters, 12, 319 (1987)

–D. Du, J. Squier, S. Kone, G. Korn, G. Mourou, C. Bogusch, C. Cotton, Optics Letters, 20, 2114 (1995)

–D. Strickland, G. Mourou, Optics Communications, 56, 219 (1985)

11.4 Safety

–K. Robinson, Photonics Spectra, Oct. (1998)

12 Contact Information

Main Office

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ORC Alignment Procedures

1. Place power meter at the ORC output.

2. Set the current to 20 amps with no power to the Q-switch driver. The laser will be operating in Continuous Wave mode.

Note: It is assumed the oven controller has already been calibrated.

3. Open Shutter.

4. Tweak the LBO crystal's horizontal rotation angle first. There should be three "peaks" where power is maximized; align the crystal on the central peak

5. Tweak the two end mirrors to try to increase the output power. Alternate the adjustments between the LBO crystal and the end mirrors until the maximum power at 20 amps is found.

6. Periodically check the beam going through the crystal. If the beam moves off center during the CW optimization then re-adjust the crystal's X and Y position. **Do not make this adjustment unless the Q-switch driver is off.**

7. Increase the current by two amps. Repeat steps 4-6 until you reach 29 amps or you obtain 5 Watts of power.

Note: 5 Watts of power might not be obtainable with an LBO Crystal.
Note: The next steps are to align the Q-switch

8. Close ORC shutter

9. Place beam block in the output path of the 532nm (Green) beam

10. Turn on the RF power supply and turn the 3 position Modulation control knob to the off position

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16. Re-inspect the lamp and then close the lamp housing. Replace the lamp contacts if there is evidence of corrosion.

17. Secure the lamp housing cover by tightening the eight (8) 8-32 screws in a "boot-lace" pattern (See Figure 1). Use several iteration of the "boot-lace" pattern until all the screws are tight. Tighten firmly using a ball driver. Do not use excessive torque. Do not force the screws. Replace the screws or re-tap the holes if necessary.

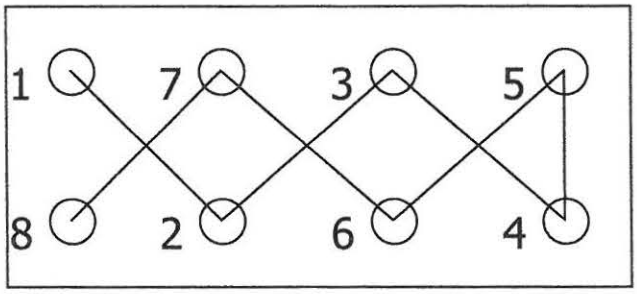
18. Slide the long beam tube back into place.

19. Replace the Q-switch assembly and the M1 end mirror.

20. Align ORC cavity as follows

Fig. 1

Top View of the Lamp Housing.



?oot-Lace?Pattern

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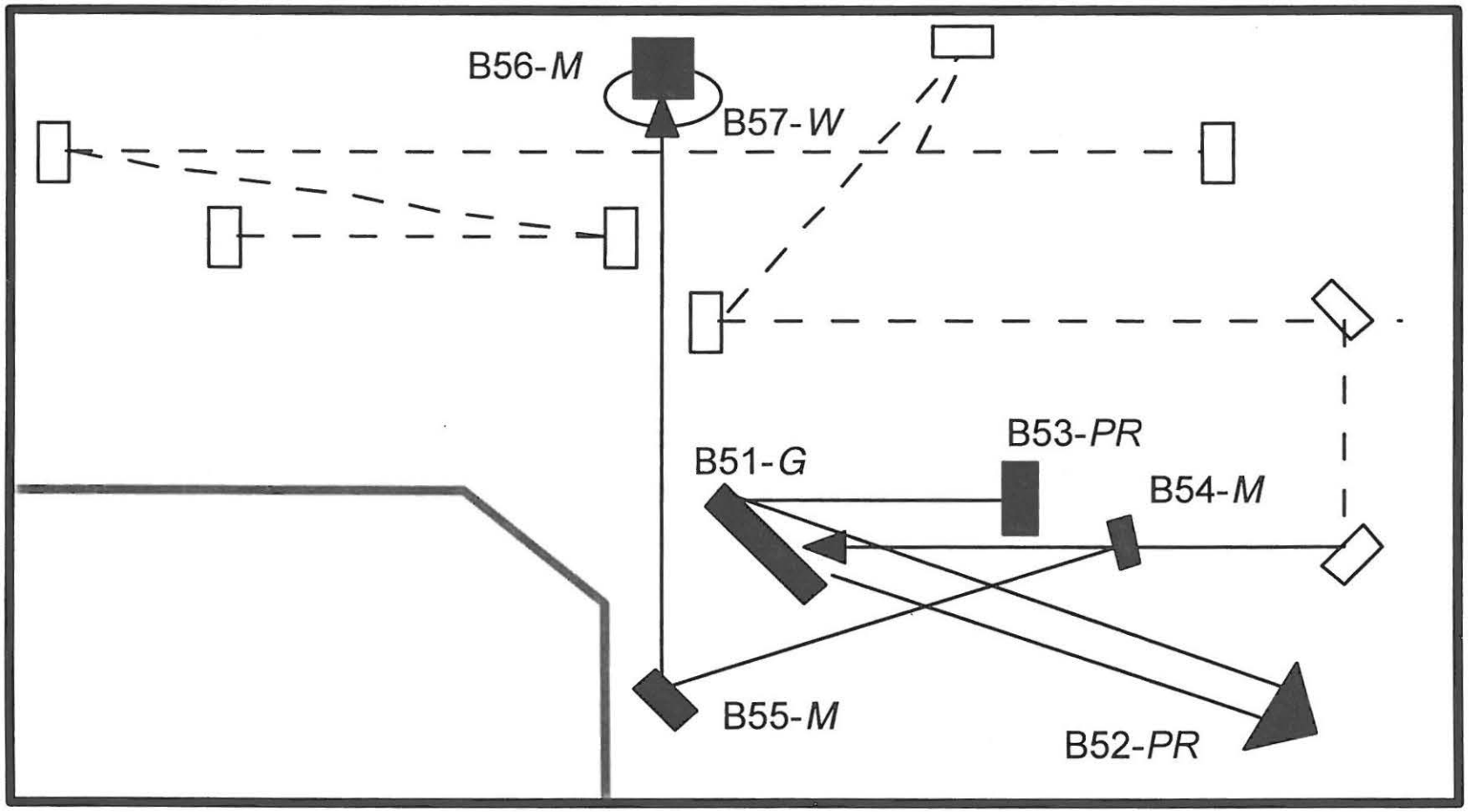
The Layout of the Compressor for the CPA-2001



Legend:
G grating
M mirror
PR prism
W window

ORC Cavity condensed Alignment Procedure

IR Operation

After the SAM (M4, 10 cm in diagrams) mirror is replaced, with Q-switch turned off, plug the oven control cable into the KTP mount and turn the power supply and lamp back on. (In your case it should already be on). If the oven controller hasn¡ft been cali brat edt o 75-755 ohms then do so at this time. (Your reading was 730 ohms, so it is best to go ahead and calibrate. To do so, adjust the fine pot on the oven controller (found in the same location as the white plugs in the power supply) to read 750-755 ohms. Be sure to have the power supply on to about 21 amps and the Q-switch off while this is performed). Wait about 15 minutes after the oven has been calibrated to make sure the temperature will remain stable. Open the shutter and look through the window on the KTP mount cover at the face of the crystal. If the crystal is properly placed a green beam can be seen through the crystal. If the crystal is not centered adjust the X and Y-axis of the mount to center the crystal in the beam.
Close the shutter and remove the beam tubes between the KTP and SAM mount (M4, 10cm). Remove the O-ring in the SAM mount so it doesn¡ft get bur ned and s moke t he opti c Open t he shutter and locate the surface reflection from the KTP on the SAM mount. Adjust the vertical and horizontal angular axes on the KTP mount to put the reflection on the edge of the aperture in the SAM mount in the 3 o¡fld ock positi on Then r-adjust the horizontal angle to find maximum output power. Be careful to wear appropriate goggles (532 nm OD>4) when adjusting the KTP. Also be careful not to get dust on the crystal when the cavity is open. As soon as the crystal is properly aligned close the shutter and replace the O-ring and beam tubes. Be sure the SAM mirror is free of any dust or debris, or it will burn. Proceed with 532 optimization.

532 nm Optimization

Move the power meter head to start of regenerative amplifier, as usually done to begin operations. Start at 21 amps current and with no power to the Q-switch driver, operating in CW mode. It is assumed the oven controller has already been calibrated, so open the shutter. Tweak the crystal¡fs hori zont al r ot ati on angl e first. There shoul d be t hree ¡ peaks¡ – wher e powe maximized; align the crystal on the central peak. Then tweak the SAM mirror to try to increase the output power. Tweak only the top corner adjustment screw. It is a good idea to remove the set screws holding the long telescoping beam tube in the fixed mirror mounts, move the tube a little and peek down the holes to see if the beam is well placed (centered under the set screw holes). Alternate these adjustments between the crystal and the end mirror until the maximum power at 21 amps is found. Periodically check the beam going through the crystal. If the beam moves off-center during the CW optimization then re-adjust the crystal¡fs Xand Yposi ti on Do not make this adjustment unless the Q-switch driver is off. Once a maximum power is found record it and increase the current to 23 amps, tweak again, then increase current to 25 amps and tweak again.
In CW operation 5 watts should be found at or under 25 amps through the lamp.

Before going to pulsed operation the Q-switch must be properly aligned. With the q-switch diver on but the modulation off, at the power meter face, a faint green beam may be seen. If so, loosen the clamping screw on the Q-switch mount and turn the adjustment screw to set the proper Q-switch angle. The restoring spring in the Q-switch mount is weak so it is necessary to push the vertical plate on the Q-switch mount against the adjustment screw. As the Q-switch is rotated the amount of light ¡ l eaki ng¡– thr ough t he opt ic will vary There are t wo angles where t h

amount of light is minimized. Adjust the Q-switch for one of these nodes and then tighten the clamping screw. Increase the current by a Watt or two until green light shows again and then ¡ d pi– t he -switch again. Keep doing this until the Q-switch can no longer ¡ hd d off i– t he l ase i.e., light leaks through the Q-switch even though it is at the optimum angle. If the Q-switch can not hold off the laser when there is at least 29 amps current then re-dip the Q-switch starting back at low current or increase the RF power. If the q-switch already holds off the laser to 29 amps, then do not adjust anything. Once the Q-switch is satisfactorily aligned, walk the current back down to 20 amps, checking for leaky spots, and then close the shutter. With the current back to 20 amps and the frequency at 1 KHz make sure the oven resistance is around 750 ohms. (It should be already at 1 KHz). The laser¡fs po wer is maxi mized at 1 KHz so be very cauti ous when tuning the KTP and SAM mounts. Do not adjust the LAM mount at 1 KHz. Do not adjust the laser at 1 KHz if the output power is more than 8 Watts; doing so may damage the KTP. Always monitor the oven resistance when the laser is operating at 1 KHz. The oven resistance should not drop more than 10 ohms at any time; if it does the KTP has burned. Ideally the oven resistance will be within 5 ohms less than static oven resistance. Set the current so the output power is about 5 Watts. Carefully adjust the crystal¡fs hori zontal angle t o obtain maxi mum output. Only small angular adjustments are needed at this point in the test. Then tweak the SAM mount. Alternate between the KTP and Sam mirror. Turn the current up to obtain 6.5 Watts and re-tweak the laser. Turn the current up to obtain about 7.5 Watts and re-tweak. If at 7.5-8 Watts the laser seems stable then slowly turn up the current while monitoring the power meter and the oven resistance. If the oven resistance drops suddenly, or power decreases suddenly, or the laser becomes unstable, back off the current and check for a damaged KTP or burned mirrors. Also check the Q-switch alignment otherwise increase current until the waveform on the scope starts to collapse in on itself; this is the Q-switch failing to hold off the laser. If 12 Watts is obtained before the waveform collapses, do not increase the current beyond that point. If 12 Watts is not obtained go back to 5 Watts and re-tweak laser. Stability should be better than 3% peak-to-peak at powers above 8 Watts.

At this point it will be time to bring the green beam into the regenerative amplifier cavity. The first turning mirror outside the output coupler sends the beam into a prism aligned at minimum deviation. This needs to be rechecked. What I would do next is to again turn off the Q-switch (and low power also) and cavity dumped very late (delay two very late or injection shutter off) and tweak the two turning mirrors after the prism until it is brought into the Ti: sapphire rod. Slowly tweak the two green turning mirrors prior to the regenerative amplifier cavity until the regenerative amplifier starts to lase. Tweak for fastest build up. Then turn Q-switch on and inject and fine tweak for best performance.

B205

☐ Warranty
☐ Non-warranty
☐ Installation

Clark-MXR, Inc.

SERVICE REPORT

Customer Name: Young-Dahl Jho	#E526
Company/Institution/Organization: NHMFL	Start Date: 7/20/05
Phone:	End Date: 7/21/05

Address: NHMFL

Tallahassee, FL

Problem Reported: Poor compression and Training

Found: Improper cooling of the YAG rod and lamp, broken UV filter in Lamp housing, Defective lamp and poor compression

No modelocking. Loud noise coming from the lamp housing. Damaged grating.

Action Taken: Warranty replacement of the lamp, and replaced UV filter. This stopped the noise that was being generated in the lamp housing. ORC out put power 7W at 25Amps. System output 800mW. System lost modelock after 5 hours of running. Customer was able to tweak wave plates to obtain modelocking again. Compression was about 300A/C. Tweaked angle of grating and adjusted distance of the right angle mirror mounts and rotated the grating to obtain compression 230A/C (153fs).

Training: Customer was retrained on modelocking and was given instructions. Customer was able to lose modelock and find again. Customer repeated this several times. You must use an analog scope to look at modelocking

Customer was given compression layout schematic. Customer was able to retrace alignment path.

Customer was given region layout schematic. Customer was able to retrace beam path in the region.

All of customers question where answered and customer feels more informed about his CPA system and how to optimize and use it properly.

			Output Power	800mW
			ORC Power	7W
			Delay #1	
			Delay #2	
Part No./Description		Qty	Price	Extended
	Lamp	1	Warranty	0
	UV filter *	1	26.00	26.00
**Customer reset quote for new grating				
* price includes installation discount				
			Subtotal	
Labor	Hours 8	Rate: $175/hour (8 hour minimum)		
Travel	Zone Charge			$1700.00
			TOTAL	$1726.00

Work By Amber Hollenbeck	Follow-up Required NO
Customer Signature	

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Clark-MXR, Inc.

Action Taken Cont.

Customer was not able to benchmark compression with anything other then CMXR s Mini AC. I suggest that the customer obtain Mini AC or similar equipment in order to make sure system is optimized. I also suggest that the system be purged with nitrogen to help stability and reduce oxidation of the compressor grating. The CPA system should be turned on several times a week to make sure that the system is optimized. The system should also be allowed to run for several hours. This will help with optimizing the system in the future This will not only help with the customers knowledge of the system but will also help prevent down time in the future.

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3205

Clark-MXR, Inc.

☐ Warranty
X Non-warranty
☐ Installation

SERVICE REPORT

Customer Name Jun Kono / Young-Dahl Jho	SO# D564
Company/Institution/Organization National High Magnetic Field Laboratory	Start Date December 14, 2004
Phone 850 - 644-0311	End Date December 15, 2004
Address 1800 E. Paul Dirac Dr.	
Tallahassee, FL 32310	

Problem Reported: System required to be set up after construction of lab.

Action Taken: Inspected the system and found it in overall good condition. The CPA needed the YAG rod seals replaced, and the YAG head o-ring required to be replaced. Removed and replaced the required o-rings. Made fin adjustments to the ORC for 7.5 W of output power at 25 Amps. The regen and compressor required minor adjustments to achieve 840 mw of output power. The output beam was put thru a BBO crystal and the compressor was aligned maximizing the doubling efficiency. The CPA still has a KTP crystal instead of a LBO crystal.

The customer had a RSK present and there is no charge for the YAG head o-ring.

Part No./Description	Qty	Price	Extended
N/A			$0.00
		Subtotal	
Labor 6 Hours	Rate: $175/hour (8 hour minimum)	$1400(min)	$1400.00
Travel $1700.00			$1700.00
		TOTAL	$3100.00

Work By	Follow-up Required
Customer Signature	

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Clark-MXR, Inc.

SCH B205

[x] Warranty
[ ] Non-Warranty
[ ] Installation

SERVICE REPORT

Customer Name: Young-Dahl Cho	# C091S
Co/Institution/Organization: Florida State University	State Date: 5/14/2003
Phone: (850) 644-0311	End Date: 5/16/2003
Address: High Magnetic Field Lab	
1800 E. Paul Dirac Dr.	
Tallahassee, FL 32310	

Problem Reported: THE SHUTTER NOT RESPONDING

Action Taken: OBSERVED LASER, AND TALKED TO YOUNG-DAHL, SUSPECT THAT MODE-LOCK MAY HAVE BEEN FLAKING OUT DUE TO TEMPERTURE VARIATIONS, DESCRIBED HOW TO TROUBLE-SHOOT THIS PROBLEM IN THE FUTURE.

Part No./Description	Qty	Price	Extended
		Subtotal	
Labor — Hours — Rate: $125/hour (4 hour minimum)		$500.00 (min).	
Travel — Zone Charge			2,000.00
		TOTAL	

Work By: [signature]

Customer Signature:

Follow-up Required: BY PHONE

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Installation and Service Diagnostics Form

To be checked on every service/installation trip

Date 5/15/03
Location NHMFL
Customer KNO
Laser CM 1323

Chiller

Type VWF
Temperature 19.2
Water Flow Rate 5L/m

Laser Diode

Power 150
Current 26.9
Fiber Coupling (yes/no)

SERF

PPLN Temp
Frequency
Amplitude

ORC

Power ≈ 7.75W
Current 27.5 Amps
Hours 395
Pulse Width

Power
Current

Regen

Power > 800mW
Pre-compressor Power
Frequency 1K
Stability Good
Pre-pulse
Post-pulse

DT 505

Delay 1 94.39
Delay 2 85.85
Delay 3
HV 1 9.0
HV 2 14.8
RF Divider 10

Equipment Available at Customer Site

Oscilloscope ✓
Power Meter ✓
Autocorrelator
Camera
Other Peripheral Equipment:

Clark-MXR, Inc.

- [ ] Warranty
- [x] Non-Warranty
- [ ] Installation

SERVICE REPORT

Customer Name David Reitze	# C206W
Co/Institution/Organization University of Florida	State Date 10/9/03
Phone 352 392-3582	End Date: 10/10/03
Address Dept of Physics	
PO Box 118440	
Gainsville, FL 32611-8440	

Problem Reported SHUTTER WOULD NOT OPEN

Action Taken FOUND THE PROBLEM TO BE A BAD KTP MOUNT WITH A GRAY-TRACKED CRYSTAL. LUBE, REMOVED MOUNT AND CRYSTAL, REALIGNED ORC, REVIEW, AND COMPRESSOR, LASER WORKS FINE

OUTPUT POWER = 800mW
PRE-COMPRESSOR - 1.3W
ORC - 8W
DELAY1 - 085.30
DELAY2 - 086.02

Part No./Description	Qty	Price	Extended
KTP CRYSTAL AND MOUNT	1	—	—
		Subtotal	
Labor / Hours / Rate: $125/hour (4 hour minimum)		$500.00 (min)	
Travel / Zone Charge		1,400.00	
		TOTAL	$1,900.00

Work By JEREMY MATHIS

Follow-up Required

Customer Signature

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Clark-MXR, Inc.

- [x] Warranty
- [ ] Non-Warranty
- [ ] Installation

SERVICE REPORT

Customer Name: Young-Dahl Cho	# C004S
Co/Institution/Organization: Florida State University	State Date: 1/8/2003
Phone: (850) 644-0311	End Date: 1/10/2003
Address: High Magnetic Field Lab	
1800 E. Paul Dirac Dr.	
Tallahassee, FL 32310	

Problem Reported: LOST MODE-LOCK

Action Taken: TWEAKED ALL WAVE-PLATES AND RE-CENTERED THE MODE-LOCK. AFTER THIS HOWEVER THE REGEN HAD TO BE REALIGNED DUE TO BAD MODE-LOCK. THIS WAS FROM THE CUSTOMER TRYING TO DRIVE INTO THE LASER. THIS WAS EXPLAINED NOT TO BE SOMETHING TO TOUCH IN THE FUTURE AS LONG AS THE LASER IS UNDER WARRANTY

Part No./Description	Qty	Price	Extended
		Subtotal	
Labor — Hours — Rate: $125/hour (4 hour minimum)		$500.00 (min).	
Travel — Zone Charge			1,700.00
		TOTAL	

Work By: JEREMY

Follow-up Required: NONE

Customer Signature:

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File with B205

Clark-MXR, Inc.

Installation Report

Installation Engineer Michael Godkin	Date 10/14/02
Customer Jun Kono / Xing Wei	Installation SO # 2191

System Includes:	
CPA-2001/2010	CPA 2001
NOPA	
STORC	

System Specifications:	CPA 2001 / 2010			Other Products		
	CPA 2001 Spec	CPA 2010 Spec	Tested	Equipment	Expected	Tested
Output Energy	800 mW	1W / 1.6W	900mW			
Rep Rate	1KHz	1Khz / 2 KHz	1 KHz			
532nm Power	> 8.3 W	> 8.3 W	7.0W			
Output Mode (Visual Insp.)	Near TEM_{00}	Near TEM_{00}	Near TEM_{00}			
AC Trace FWHM*	150 fs	150 fs	220 AC	Frog		
Pre-pulse contrast ratio*	500 to 1	500 to 1	1000 to 1			
Post-pulse ratio*	100 to 1	100 to 1	5 or to 1			

* Measurement may require customer-provided diagnostics

Description of Test Conditions
Test #1: Lab Is In Less than ideal conditions, Proceeded to Install CPA
Test #2: at the Customer Request. See diagnostic form for Lab upgrades.
Test #3:

Customer(s) understands laser safety issues relating to their system. JK (Initials)

Customer's Signature: Jun Kono Date: 16 Oct 2002

Clark-MXR, Inc. Representative's Signature: Date: 16 Oct 2002

Comments may be made on the reverse side of this form or on separate sheets and attached to this form.

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Installation and Service Diagnostics Form

To be checked on every service/installation trip

Date 16 Oct 2002
Location NHMFL
Customer Dr. Kono
Laser CM 1323

Chiller

Type UWR
Temperature 20°C
Water Flow Rate 1.5 gpm

Laser Diode

Power 150
Current 26A
Fiber Coupling (yes/no) Y

SERF

PPLN Temp 146.6
Frequency 34.4 MHz
Amplitude 10

ORC

Power 7W
Current 25 Amps
Hours 224
Pulse Width N/A

Power X
Current X

Regen

Power 900mW
Pre-compressor Power 1.4
Frequency 1 KHz
Stability good
Pre-pulse 1000 to 1
Post-pulse 500 to 1

DT 505

Delay 1 8428
Delay 2 8585
Delay 3
HV 1 ~~3.4~~ 3.2
HV 2 3.34
RF Divider 16

Equipment Available at Customer Site

Oscilloscope ✓
Power Meter No
Autocorrelator Frog
Camera Frog
Other Peripheral Equipment:

Notes and Comments

Lab conditions are less than Ideal.
Customer needs the following Items
Door to prevent access into Laser Lab. Lab requires better Enviromental control (less Humidity). A Ceiling on Lab.
Any Items that may fail must be Analized to determin IF the Cause came from the Enviroment of the Lab.

Clark-MXR, Inc.

Soft
B205

☐ Warranty
☐ Non-warranty
☐ Installation

SERVICE REPORT

Customer Name: Young-Dahl Jho	# 5510
Company/Institution/Organization: NHMFL	Start Date: 4/26/05
Phone:	End Date: 4/27/05
Address: NHMFL	
Tallahassee, FL	

Problem Reported: Modelocking problems

**NOTE: This is the second service visit in the service contract

Action Taken: Checked the Diode board and output power of the diode. Diode reads lower then actual output. Moved wave plates and BRF to original white markings. Turned up diode to 165mW and 310mA. Found modelocking quickly. Stretcher output Power is 1.5mW. PPLN temp 1480Ω. There is 1.5V of modelocking signal without the filter. Turned on system, had to tweak injection mount slightly to optimize pulse train System output power is 760mW after customer 90/10 beam splitter. DT505 setting for 1Kh are RF = 16 Delay 1 = 08544 Delay 2 = 086D1 Delay 3 = 084FD. Chiller temp 18.6°C. Customer put beam thru doubling crystal and was happy with the results. Modelocking was lost once on the second day in the morning, but the same regime was found again within seconds. The laser has been stable since.

		Output Power	See above
		ORC Power	
		Delay #1	
		Delay #2	
Part No./Description	Qty	Price	Extended
		Subtotal	
Labor	Hours 8	Rate: $175/hour (8 hour minimum)	$1400.00 (min)	SC
Travel	Zone Charge			500.00
			TOTAL	500.00

Work By Amber Hollenbeck	Follow-up Required NO
Customer Signature	

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Clark-MXR, Inc.

☐ Warranty
X Service
☐ Installation

SERVICE REPORT

Customer Name Jinho Lee	SO # F507
Company/Institution/Organization NHMFL	Start Date March 14, 2006
Phone 850-645-3265	End Date March 15, 2006
Address 1800 E. Paul Dirac Dr.	
Tallahassee FL, 32310	

buy one

Problem Reported Low ORC output power

Action Taken Inspected the system and discovered that the KTP crystal had graytracked. Installed LBO crystal and Aligned the ORC.

The ORC power did not meet spec and the system was shut down and inspected the mirrors of the cavity. Discovered burns on the following

Optics. 10cm, 20cm, Output coupler, End Mirror, and YAG rod. The burns on the 10cm, 20cm, and End mirror were able to rotated and

did not require replacement. Had to replace the Output coupler and the YAG rod assembly. Aligned the system for 7 watts of output power

at 28 Amps. The lower and upper ceramic reflectors are original and should be replaced to improve efficiency and improve the lifetime of

lamps. Aligned the Regen cavity for 900mw of output power. Change the grating position in its mount and aligned the compressor for 154fs

The output power of the customer's TOPAZ is 135-140mw at 1300 um. The system was shut down and started repeatedly to test reliability

Replaced the ORC head clamp bar since a screw was broken off in to previously.

Part No./Description	Qty	Price	Extended
ORC output coupler	1	$644.00	$644.00
LBO crystal	1	$2800.00	$2800.00
YAG Rod Assembly	1	$2509.00	$2509.00
ORC Head Clamp Bar	1	$150.00	$150.00
		Sub total	$6103.00
25% discount on Parts	1		$1525.75
		Subtotal	$4577.25
Labor — 12 Hours — Rate: $175/hour (8 hour minimum)		$1400(min)	$2100.00
Travel — Zone Charge		$1700.00	$1700.00
		TOTAL	$8377.25

Work By	Follow-up Required
Customer Signature	

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Clark-MXR, Inc.

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Dexter, Michigan 48130

Tel: (734) 426-2803
Fax: (734) 426-6288
Web: www.cmxr.com

Date: 4/21/06

Clark-MXR, Inc.
Equipment Loan Agreement

An Agreement made between:

Clark-MXR, Inc., 7300 W. Huron River Dr., Dexter, MI 48130 ("CMXR") and
Jinho Lee - NHMFL ("User").

CMXR agrees to loan to the User equipment belonging to CMXR and described as
Handles and Decoupling tools (the "equipment")

User agrees to return equipment by
June 2006

Price of equipment
$ 500.00

The loan of the equipment is subject to the following conditions:

1. The equipment shall be and remain at all times the property of CMXR.
2. If equipment has not been returned to CMXR by agreed date, User shall pay CMXR for the cost of the equipment.
3. Remit payments to: Accounts Receivable, Clark-MXR, Inc., 7300 W. Huron River Dr., Dexter, MI 48130.
4. All payments are due 30 days after invoicing.
5. The customer is responsible for the cost of shipping to and from CMXR facilities.
6. The User shall be responsible for all costs associated with taxes, custom fees, etc.
7. The User shall be responsible for the repair or placement of the equipment in the event that it is lost or damaged, including loss or damage during shipping or delivery to or from the User.
8. The User shall make every effort to ensure that the equipment is used, maintained and stored in a proper manner. The equipment shall not be moved from the regular or agreed upon premises or operations of the User with the prior written approval of CMXR.
9. In the event of damage to the equipment, the User shall not undertake or arrange for the repair of the equipment, other than routine maintenance, with the prior approval of CMXR. The User shall not alter the equipment or change the use for which it was intended without the prior written approval of CMXR.
10. CMXR makes no claims regarding the condition of the equipment or its suitability for any particular scientific or other purpose.

11. The User agrees to indemnity CMXR against any expenses, claims, damages, or actions arising out of a breach of this Agreement or arising out of a breach of this Agreement or arising out of the User's possession or use of the equipment.
12. The User agrees to return the equipment in the same condition in which it was received, normal wear and tear accepted.
13. CMXR reserves the right to terminate this Agreement at any time upon 30 days written notice to the User. The User agrees to return the equipment immediately at the end of the notice period.
14. The User shall not assign this Agreement or assign or sublease the equipment without the express written consent of CMXR.
15. This Agreement constitutes the entire agreement between the parties. Any amendment to this Agreement must be in writing and signed by both parties.
16. This Agreement shall be governed and interpreted according to the laws of Michigan.
17. If the User fails to return the equipment at the end of the loan period the User agrees to pay CMXR for the current retail price of the equipment within 30 days of being invoiced.
18. Additional Terms and Conditions [Set out below in the space provided.] Parties should initial each additional term.

Representatives of the company and the user must sign this agreement before the equipment is released to the user.

Signature:	Signature: Bruce L Brandt
Amber Hollenbeck (signed) CMXR Representative	User Representative
Customer Service Print Name and Title	Bruce L. Brandt, Head of DC User Program Print Name and Title
April 21, 2006 Date Signed	4/21/06 Date Signed

Fax Cover Sheet

AST

To: James Mundy
Company: National High Magnetic LAB
Fax: 850-644-1243
Date: 4/27/2006

From: Jennifer Schalesky
Phone: 814-472-0950
Fax: 814-472-5222
Pages:

ATTACHED IS THE BILL OF LADING FOR YOUR SHIPMENT 295-30-O-36224

YOUR COMPANY MUST CALL R&L CARRIERS AT: 800-940-0138 FOR THE PICKUP

ONCE THE SHIPMENT HAS BEEN PICKED UP BY R&L Carriers
PLEASE FAX THE BILL OF LADING WITH THE CARRIER PRO # TO: 814-472-5222
IF YOU HAVE ANY QUESTIONS, PLEASE CONTACT Jennifer Schalesk
AT: 814-472-0950

THANKS
Jennifer Schalesky

thanks

3 days transit
$ 541.49

Clark-MXR, Inc.

INITIAL INSPECTION REPORT

This form is to be attached to the appropriate **signed** pre-service customer report. Do not proceed w/o a form signed by the customer

Customer Name Jinho Lee/Reitze/Branson/ Tallahassee	**RMA# 13561**

Problem Reported

1. Possible water damage to the SERF. No modelocking.
2.
3.

Suggested additional procedure (This information will be provided to the customer. His written authorization will be obtained prior to any additional work)

Upper plate in SERF laser removed to check for water damage in fiber tray. Fiber tray showed white mineral deposits, usually caused by Water damage. All modelocking optics showed watermarks and degradation. All optics needed cleaning. Right hand fiber collimator (looking from the top of the laser) was extremely bent. It did not appear broken, but it needed to be straightened.

System will need complete re-alignment.

Part No./Description	Qty	Unit Price	Extended
This is a preliminary report only. Charges have not been assessed.			
		Subtotal	
Labor estimate (hours)	Rate: $125/hour		
		TOTAL	

Service Engineer Amber Hollenbeck	Additional comments:

Customer signature: By signing and returning to us this document you accept the charges listed above (those are in addition to the charges listed in the "pre-service customer report")

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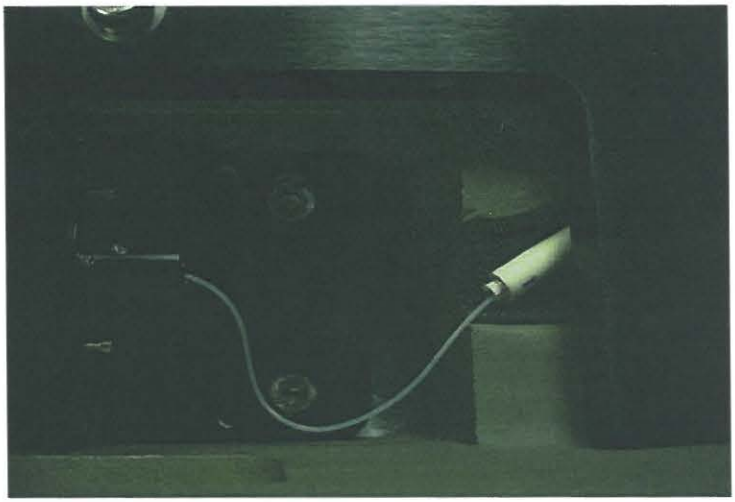
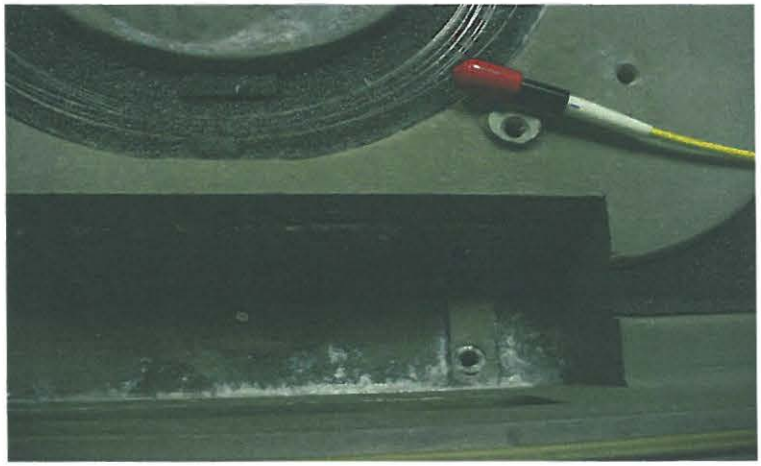
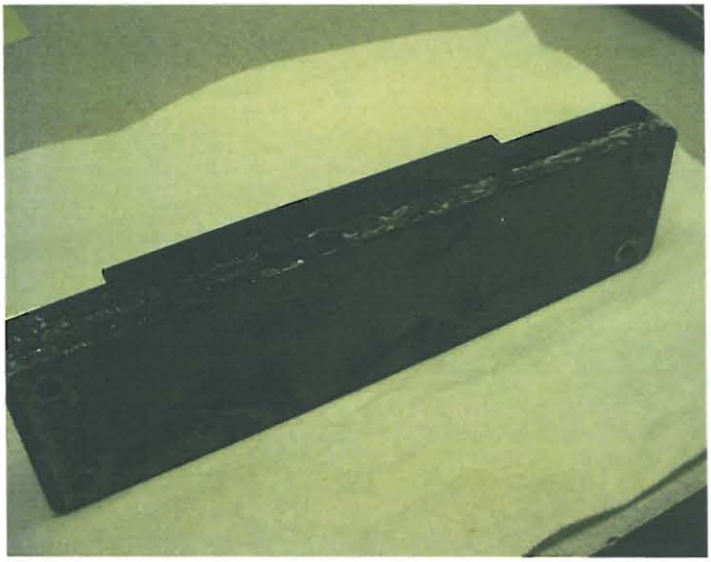
Initial Inspection Report RMA# 13561.







Pictures of the fiber tray, modelocking optics block, and collimator.

Clark-MXR, Inc.

☐ Warranty
X Non-warranty
☐ Installation

SERVICE REPORT

Customer Name Jinho Lee	**SO# F**
Company/Institution/Organization National High Magnetic Field Laboratory	Start Date June 13, 2006
Phone 850 - 644-0311	End Date June 14, 2006
Address 1800 E. Paul Dirac Dr.	
Tallahassee, FL 32310	

Problem Reported: Lower section of CPA requires installation after repair

Action Taken: The lower section was in place upon arrival. Connected water and electrical connections. Turn on the system and modelocking was present without needing to adjust anything. Positioned the top section to allow clean injection beam travel to the upper level. Replaced the top cover of YAG head in ORC. The pump was started and the top cover leaked check good. The ORC was allowed to warm up and required minimal adjustments to get 6.9 W of output power. The regen was optimized and injection Beam was aligned. The power before the compressor was 1.44W and 920mW of output power. The system was compressed to 147fs with the Mini A/C. A two hour stability test results were 920mW average with a Max 0f 927mW and a Mean of 918mW. The output beam was steered into the customer's TOPAZ and an output of 160mW was achieved.

During the second day start up the modelocking was not present. The BRF was slightly adjusted to regain the modelocking signal. The customer was shown the location of the BRF and how to obtain a modelock.

Part No./Description	Qty	Price	Extended
		Subtotal	
Labor 16 Hours — Rate: $175/hour (8 hour minimum)		$1400(min)	$2800.00
Travel $1700.00			$1700.00
		TOTAL	$4500.00*

Work By

Customer Signature

Follow-up Required

* This price is for the installation only of the lower section not the repair.

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Clark MXR, Inc.

FINAL IN-HOUSE SERVICE REPORT

This form is to be attached to the appropriate **signed** pre-service and initial customer report	
-Customer Name Jinho Lee/Reitze/Branson/ Tallahassee	RMA#**13561-SO#F091**
Problem Reported	
1. Possible water damage to the SERF. No modelocking.	
2.	
3.	
Action Taken and final status SERF cleaned and realigned.	
Service Engineer: Amber Hollenbeck	Date completion work: 5/09/06

Final Report (SERF)
Fiber lengths and diode : unchanged
PPLN: unchanged, PPLN reading: 1453 Ohms
Diode reading : 307 mW, 162 mA
Final Output power before stretcher : 5.3 mW.
Bandwidth : 7.75 nm centered at 771 nm.
STRETCHER:
Final output power : 2.5 mW

COST:

Part No./Description	Qty	Unit Price	Extended
		Subtotal- part	
Labor Initial inspection **5 hours** — Rate: $125/hour			625.00
Labor additional work **35 hours** — Rate: $125/hour			4375.00
Shipping Cost — Attached appropriate document			
Other fee (custom, taxes, insurance, etc.) — Attached appropriate document			
		TOTAL	**5,000.00**

Service Engineer: A. Hollenbeck	Additional comments:

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Tel: (734) 426-2803 Fax: (734) 426-6288

Clark-MXR, Inc.

7300 West Huron River Drive
Dexter, Michigan 48130

Tel: (734) 426-2803
Fax: (734) 426-6288
Web: www.cmxr.com

Date: 8-25-2006

Clark-MXR, Inc.
Equipment Loan Agreement

An Agreement made between:

Clark-MXR, Inc., 7300 W. Huron River Dr., Dexter, MI 48130 ("CMXR") and
Jinho Lee ("User").

CMXR agrees to loan to the User equipment belonging to CMXR and described as
Chiller (the "equipment")

User agrees to return equipment by
When assessment/repair is completed

Price of equipment
$3500

The loan of the equipment is subject to the following conditions:

1. The equipment shall be and remain at all times the property of CMXR.
2. If equipment has not been returned to CMXR by agreed date, User shall pay CMXR for the cost of the equipment.
3. Remit payments to: Accounts Receivable, Clark-MXR, Inc., 7300 W. Huron River Dr., Dexter, MI 48130.
4. All payments are due 30 days after invoicing.
5. The customer is responsible for the cost of shipping to and from CMXR facilities.
6. The User shall be responsible for all costs associated with taxes, custom fees, etc.
7. The User shall be responsible for the repair or placement of the equipment in the event that it is lost or damaged, including loss or damage during shipping or delivery to or from the User.
8. The User shall make every effort to ensure that the equipment is used, maintained and stored in a proper manner. The equipment shall not be moved from the regular or agreed upon premises or operations of the User with the prior written approval of CMXR.
9. In the event of damage to the equipment, the User shall not undertake or arrange for the repair of the equipment, other than routine maintenance, with the prior approval of CMXR. The User shall not alter the equipment or change the use for which it was intended without the prior written approval of CMXR.
10. CMXR makes no claims regarding the condition of the equipment or its suitability for any particular scientific or other purpose.

11. The User agrees to indemnity CMXR against any expenses, claims, damages, or actions arising out of a breach of this Agreement or arising out of a breach of this Agreement or arising out of the User's possession or use of the equipment.
12. The User agrees to return the equipment in the same condition in which it was received, normal wear and tear accepted.
13. CMXR reserves the right to terminate this Agreement at any time upon 30 days written notice to the User. The User agrees to return the equipment immediately at the end of the notice period.
14. The User shall not assign this Agreement or assign or sublease the equipment without the express written consent of CMXR.
15. This Agreement constitutes the entire agreement between the parties. Any amendment to this Agreement must be in writing and signed by both parties.
16. This Agreement shall be governed and interpreted according to the laws of Michigan.
17. If the User fails to return the equipment at the end of the loan period the User agrees to pay CMXR for the current retail price of the equipment within 30 days of being invoiced.
18. Additional Terms and Conditions [Set out below in the space provided.] Parties should initial each additional term.

Representatives of the company and the user must sign this agreement before the equipment is released to the user.

Signature:

Robert Bethke (signed)
CMXR Representative

Customer Service
Print Name and Title

August 25, 2006
Date Signed

Signature:

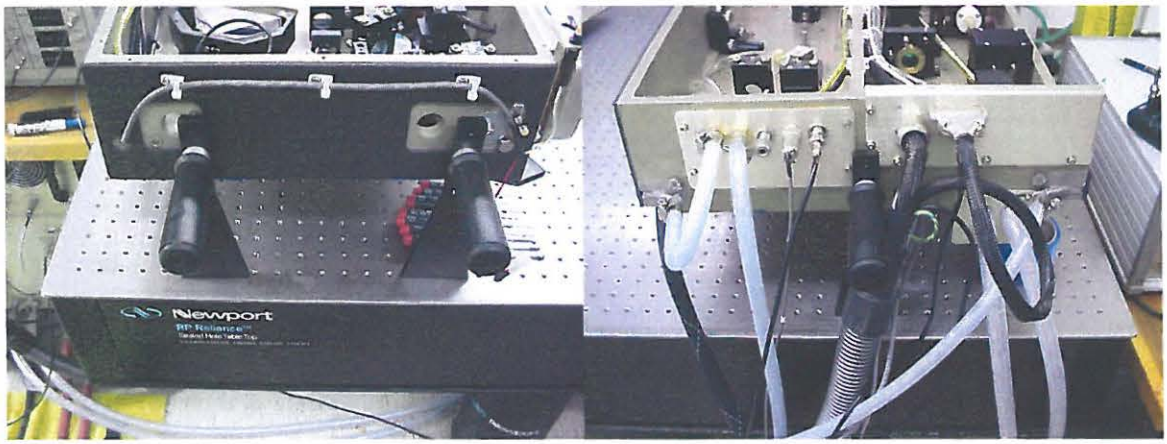
Bruce L Brandt
User Representative

Bruce L. Brandt
Print Name and Title
Head, DC Facility

8-29-06
Date Signed

Decoupling the CPA 2001

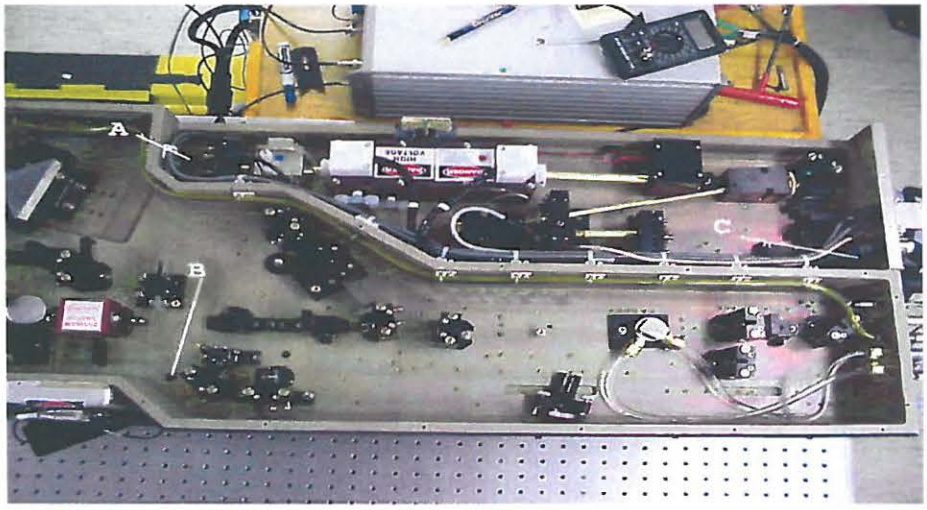
1. **Attach Decoupling tools to the outside of CPA's casting, as in the picture below. Mark casting ends to ease in re-coupling of the unit.**



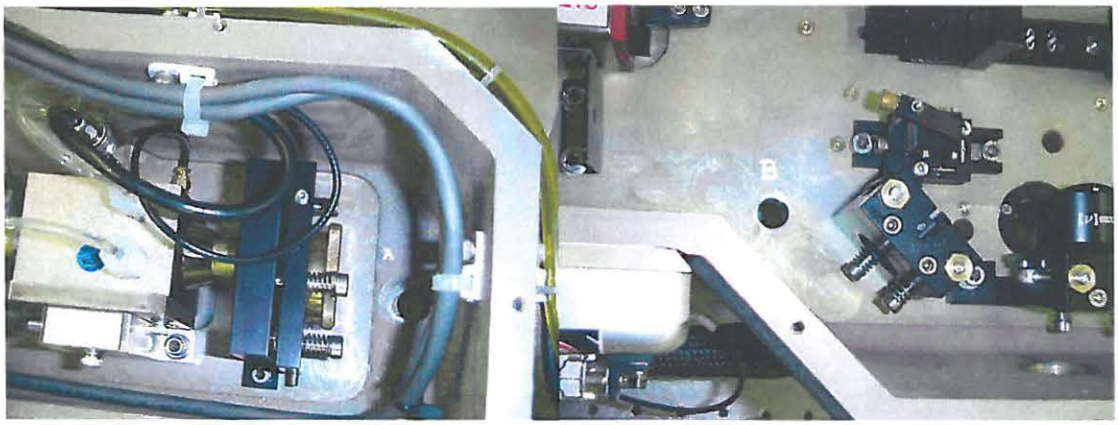
2. **Disconnect injection shutter (white connecter near the HV switches).**

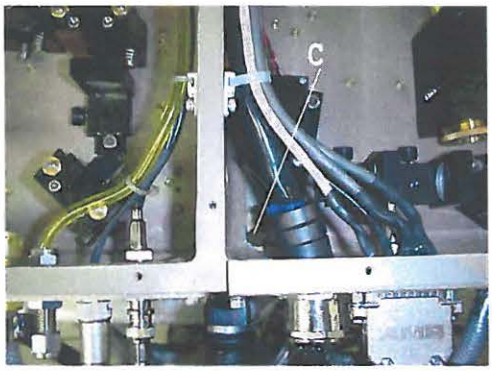
3. **Remove the two bulk ends that hold the CPA cover in place from the end of the casting.**

4. **Remove the cover off the ORC and Regen cavities.**



5. Remove the three hex bolts pictured above and below





6. Have one person on each end of unit.

7. **Lift up on decoupling tools and remove the top casting off the CPA and move it to one side.**

Clark-MXR, Inc.

Laser preparations for packaging for shipment

Bottom Half of Casting Only

1. **Turn off all power to the system. Turn off supply of water to the system, this includes turning off the chiller provided with the CPA.**

2. **Disconnect all connectors from the bottom half.**

3. **Coolant hoses need to be disconnected and casting should be drained of all water.**

4. **Handles for lifting and securing the laser to the crate must be installed. There is a left and a right handle to be used. Both handles have 3 holes for the studs/bolts on the crate. Both handles mount directly to the casting with the holes in the handles for the crate studs/bolts away from the casting. One of the handles mounts to the casting with 4 bolts and the other mounts with just 3 bolts. The handle that uses just 3 bolts is used on the congested end of the laser and that end only has 3 drilled and tapped holes for the handle.**

5. **Placing the laser handles on the crate studs/bolts is easier if the nut on the stud/bolt is slightly loosened to allow the stud/bolt to move slightly as needed. These must be re-tightened before the nuts on top of the handles are tightened. The stud/bolt may be held with strong pliers for this operation in the middle of the stud/bolt where the threads are not going to be used.**

6. **Before the bottom half of the laser is placed on the crate stud/bolts make sure the nuts for the bottom side of the handles are lowered far enough down on the stud/bolts. Verify that the metal swivel feet of the laser are all touching the crate. Tighten the nuts on both sides of the handle using a lock washer on the top nut. Verify after tightening of the nuts that the swivel feet of the laser are still flat on the wood of the crate.**

7. **Make sure bottom half of the laser system is tightly covered. A plexiglass cover is recommended.**

8. **Install the top of the crate. Label crate with "Fragile" "This end up" and shock watch devices if available. These help to minimize transit damage.**